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ISSUED QUARTERLY

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OF THE
New England Water Works Association
1949 - 1950

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George C. Houser, 220 Clyde Street, Brookline 67, Massachusetts.

THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 900 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

Initiation Fees		*Annual Dues*	
Members	$ 3.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associates	20.00
Corporate Members	10.00	Corporate Members	10.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September on such date as the Executive Committee may designate.

Supplement to the Journal of the New England Water V

DEVELOPED WATER POWER

LEGEND

● INDUSTRIAL WATER POWER

● PUBLIC UTILITY HYDROELECTRIC POWER

◉ A GROUP OF TWO OR MORE WATER POWERS

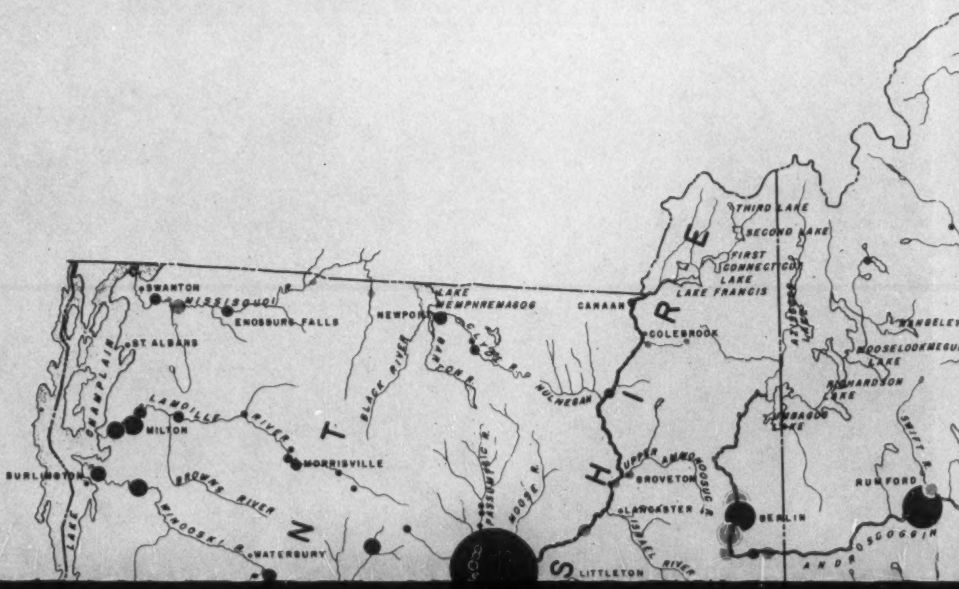
○ ○ ○ ○ ○ ○ ○ ○

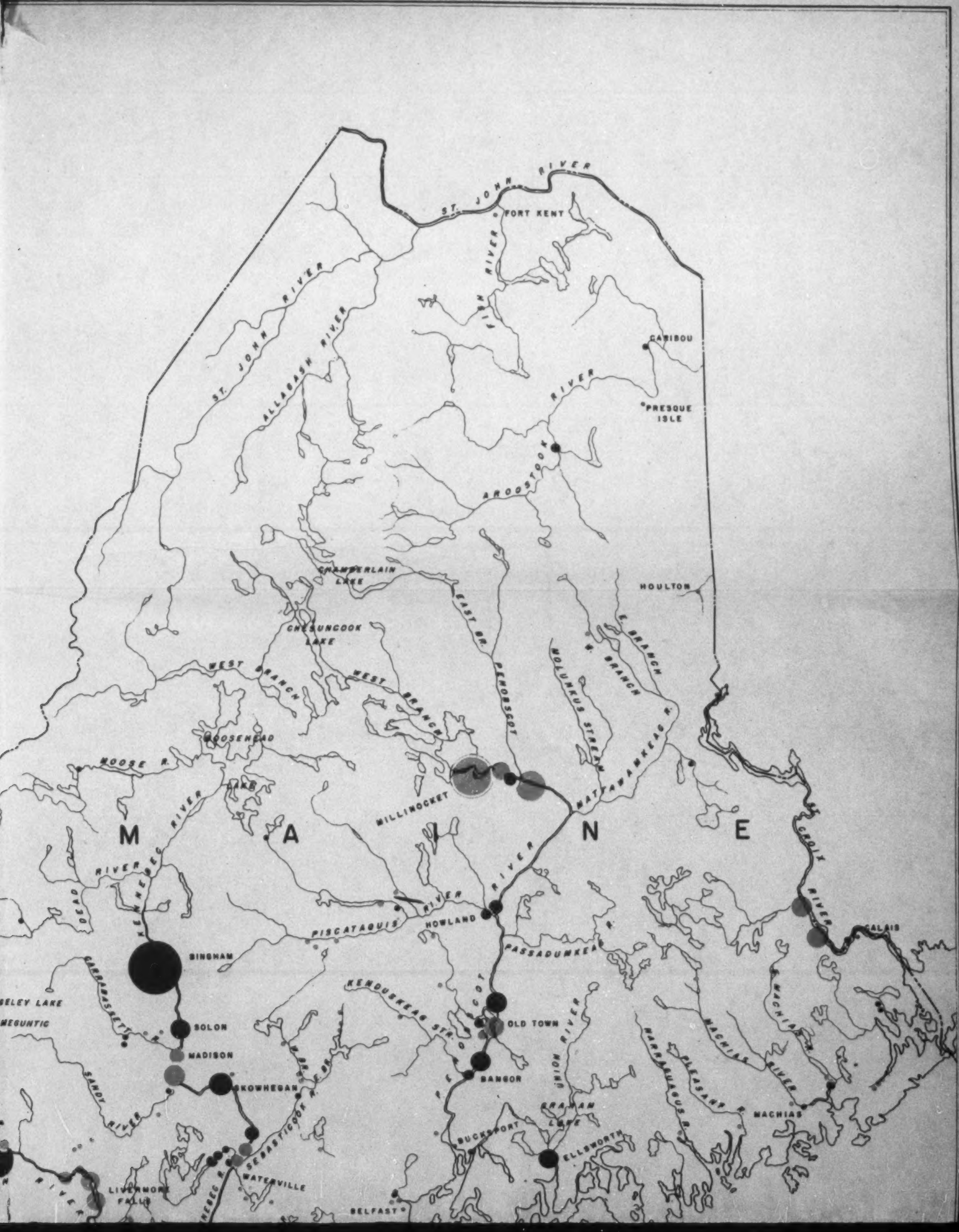
.1-.5 2 5 10 20 40 80 150

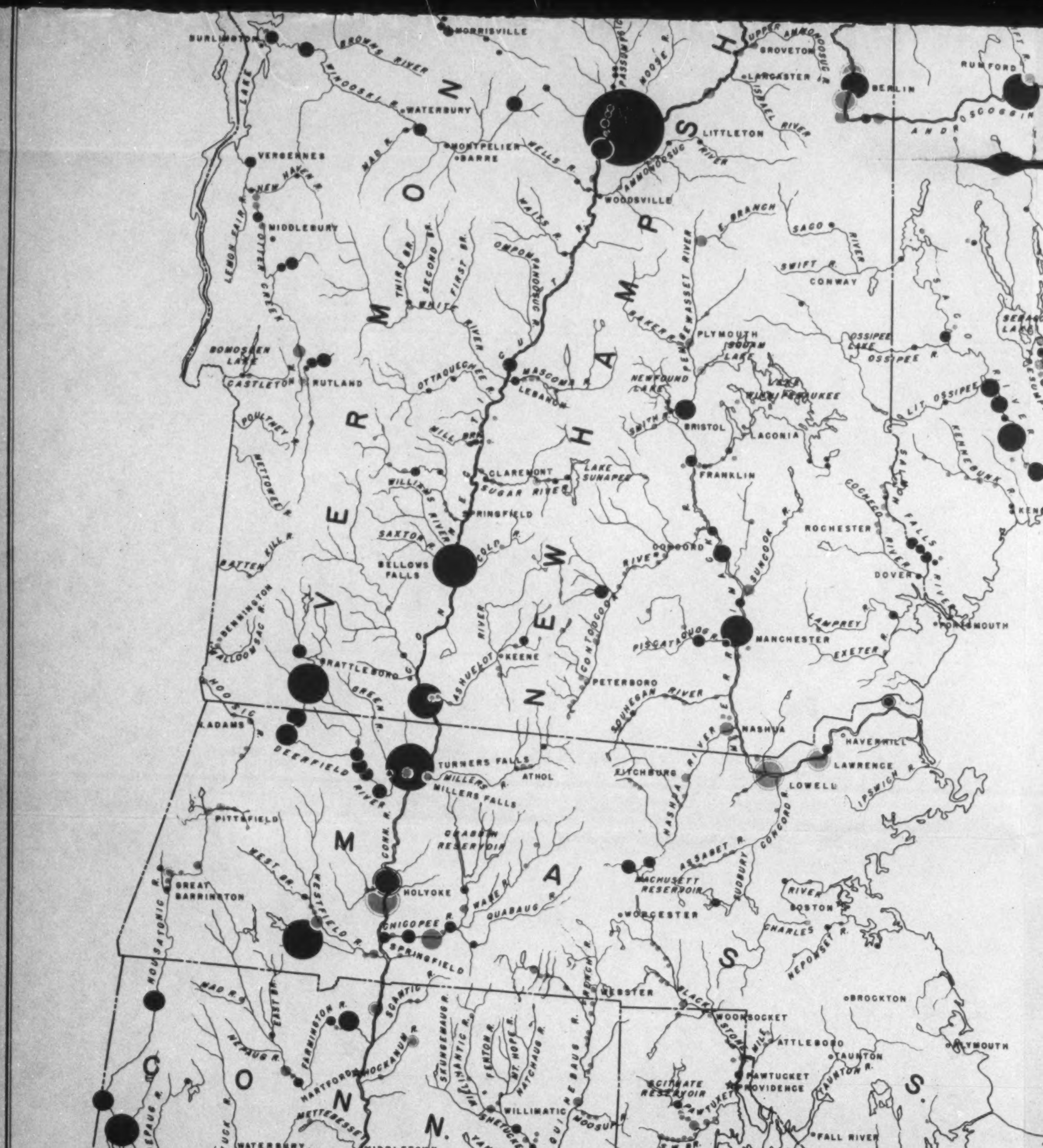
SCALE OF CIRCLES IN THOUSANDS OF KILOWATTS OF INSTALLED CAPACITY.

NOTE:

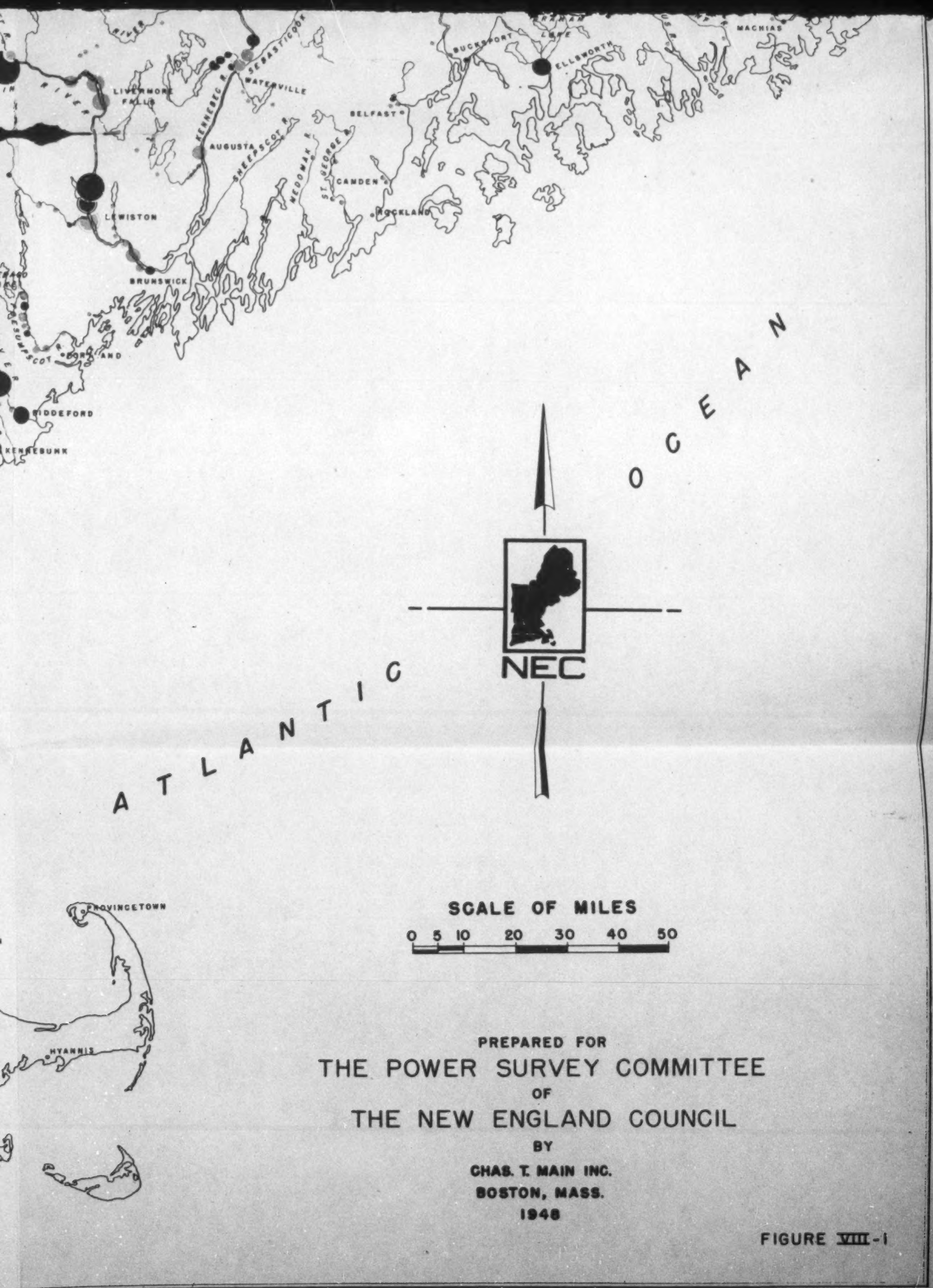
Generally, installations under 100 kilowatts are not shown.


SWANTON
MISSISQUOI
ENOSBURG FALLS
ST. ALBANS
LAKE CHAMPLAIN
LAMOILLE RIVER
MILTON
MORRISVILLE
BURLINGTON
BROWNS RIVER
WINOOSKI R.
WATERBURY
BLACK RIVER
NEWPORT
LAKE MEMPHREMAGOG
CLYDE R.
BARTON R.
NULHEGAN
PASSUMPSIC R.
MOOSE R.
CANAAN
COLEBROOK
THIRD LAKE
SECOND LAKE
FIRST CONNECTICUT LAKE
LAKE FRANCIS
UPPER AMMONOOSUC R.
GROVETON
LANCASTER
ISRAEL RIVER
LITTLETON
BERLIN
AZISCOHOS LAKE
MOOSELOOKMEGUNTIC LAKE
RICHARDSON LAKE
UMBAGOG LAKE
SWIFT R.
RUMFORD
ANDROSCOGGIN
N T
H I R E
S


ST. JOHN RIVER
FORT KENT
FISH RIVER
ST. JOHN RIVER
ALLAGASH RIVER
CARIBOU
PRESQUE ISLE
AROOSTOOK RIVER
CHAMBERLAIN LAKE
HOULTON
EAST BR. PENOBSCOT
E. BRANCH
W. BRANCH
MOLUNKUS STREAM
MATTAWAMKEAG R.
CHESUNCOOK LAKE
WEST BRANCH
WEST BRANCH
MOOSEHEAD LAKE
MOOSE R.
MILLINOCKET
M A I N E
KENNEBEC RIVER
DEAD RIVER
ST. CROIX RIVER
CALAIS
PISCATAQUIS RIVER
HOWLAND
PENOBSCOT RIVER
PASSADUMKEAG R.
BINGHAM
ELEY LAKE
MEGUNTIC
CARRABASSETT R.
KENDUSKEAG STR.
OLD TOWN
SOLON
MADISON
SKOWHEGAN
SANDY RIVER
BANGOR
UNION RIVER
NARRAGUAGUS R.
PLEASANT R.
MACHIAS RIVER
E. MACHIAS R.
MACHIAS
GRAHAM LAKE
BUCKSPORT
ELLSWORTH
SEBASTICOOK R.
KENNEBEC R.
WATERVILLE
LIVERMORE FALLS
BELFAST



VERMONT
NEW HAMPSHIRE
MASS.
CONN.
R. I.
BURLINGTON
MORRISVILLE
BROWNS RIVER
WINOOSKI R.
WATERBURY
MONTPELIER
BARRE
WELLS R.
MAD R.
VERGENNES
NEW HAVEN R.
MIDDLEBURY
LAKE
LEMON FAIR R.
OTTER CREEK
THIRD BR.
SECOND BR.
FIRST BR.
WHITE RIVER
WAITS R.
OMPOMPANOOSUC R.
BOMOSEEN LAKE
CASTLETON
RUTLAND
POULTNEY
METTOWEE R.
OTTAQUECHEE R.
MASCOMA R.
LEBANON
MILL BR.
CLAREMONT
WILLIAMS RIVER
SUGAR RIVER
LAKE SUNAPEE
SPRINGFIELD
SAXTON R.
COLD R.
BELLOWS FALLS
BATTEN KILL R.
BENNINGTON
WALLOOMSAC R.
BRATTLEBORO
WEST R.
ASHUELOT RIVER
KEENE
CONTOOCOOK RIVER
PETERBORO
SOUHEGAN RIVER
HOOSIC R.
N. ADAMS
DEERFIELD RIVER
GREEN R.
TURNERS FALLS
MILLERS R.
MILLERS FALLS
ATHOL
PITTSFIELD
WEST BR.
WESTFIELD R.
HOUSATONIC R.
GREAT BARRINGTON
CONN. R.
HOLYOKE
CHICOPEE R.
WARE R.
QUABAUG R.
SWIFT R.
CHABBIN RESERVOIR
SPRINGFIELD
SCANTIC R.
MAD R.
FARMINGTON R.
NEPAUG R.
HOCKANUM R.
HARTFORD
SKUNGAMAUG R.
WILLIMANTIC R.
FENTON R.
MT. HOPE R.
NATCHAUG R.
QUINEBAUG R.
FRENCH R.
MOOSUP R.
WILLIMATIC
SHETUCKET R.
YANTIC R.
NORWICH
THAMES R.
NEW LONDON
PAWCATUCK RIVER
MATTABESSET R.
MIDDLETOWN
MERIDEN
WATERBURY
NAUGATUCK R.
QUINNIPIAC
SHEPAUG R.
STILL R.
DANBURY
POOTATUCK R.
DERBY
NEW HAVEN
BRIDGEPORT
STAMFORD
CONNECTICUT
PASSUMPSIC R.
MOOSE R.
UPPER AMMONOOSUC R.
GROVETON
LANCASTER
ISRAEL RIVER
LITTLETON
AMMONOOSUC RIVER
WOODSVILLE
E. BRANCH
SACO RIVER
SWIFT R.
CONWAY
PEMIGEWASSET RIVER
BAKER R.
PLYMOUTH
SQUAM LAKE
NEWFOUND LAKE
SMITH R.
BRISTOL
LAKE WINNIPESAUKEE
LACONIA
FRANKLIN
OSSIPEE LAKE
OSSIPEE R.
CONCORD
MERRIMACK R.
SUNCOOK R.
PISCATAQUOG R.
MANCHESTER
ROCHESTER
COCHECO RIVER
SALMON FALLS RIVER
DOVER
LAMPREY R.
EXETER R.
PORTSMOUTH
NASHUA
NASHUA RIVER
FITCHBURG
HAVERHILL
LAWRENCE
LOWELL
IPSWICH R.
CONCORD R.
SUDBURY R.
ASSABET R.
WACHUSETT RESERVOIR
WORCESTER
CHARLES RIVER
BOSTON
NEPONSET R.
WEBSTER
BLACKSTONE R.
WOONSOCKET
MILL R.
ATTLEBORO
TAUNTON
TAUNTON R.
BROCKTON
PLYMOUTH
PAWTUCKET
PROVIDENCE
SCITUATE RESERVOIR
PAWTUXET R.
S. W. BR.
FALL RIVER
NEW BEDFORD
FALMOUTH
RUMFORD
BERLIN
ANDROSCOGGIN
SEBAGO LAKE
SACO
LIT. OSSIPEE R.
KENNEBUNK R.
S.


RIVER
LIVERMORE FALLS
KENNEBEC R.
SEBASTICOOK
WATERVILLE
AUGUSTA
SHEEPSCOT R.
MEDOMAK R.
ST. GEORGE R.
BELFAST
CAMDEN
ROCKLAND
BUCKSPORT
ELLSWORTH
MACHIAS
LEWISTON
BRUNSWICK
PRESUMPSCOT R.
PORTLAND
BIDDEFORD
KENNEBUNK
ATLANTIC OCEAN
NEC
PROVINCETOWN
HYANNIS
SCALE OF MILES
0 5 10 20 30 40 50

PREPARED FOR
THE POWER SURVEY COMMITTEE
OF
THE NEW ENGLAND COUNCIL
BY
CHAS. T. MAIN INC.
BOSTON, MASS.
1948

FIGURE VIII-1

From Calgary to Rio . . .

St. John to San Diego . . .

IT'S **LOCK JOINT**

Throughout the Western Hemisphere, Lock Joint has established its reputation as the pressure pipe of unfailing service.

Lock Joint pressure pipe is supplied in four tested and proved designs, perfected through constant research.

Whatever your water supply line problem may be, one of these four standard Lock Joint designs is certain to satisfy your requirements and give lasting service.

Made in all standard diameters from 16" to 150", Lock Joint Pressure Pipe is designed for all pressures common to American water works practice.

You are invited to inquire at any of our offices for complete data.

LOCK JOINT PIPE COMPANY

Est. 1905

P. O. Box 269, East Orange, N. J.

PRESSURE PIPE PLANTS: Wharton, N. J., Turner, Kansas

BRANCH OFFICES: Cheyenne, Wyo. • Denver, Colo. • Kansas City, Mo.
Valley Park, Mo. • Chicago, Ill. • Rock Island, Ill. • Wichita, Kan. • Kenilworth, N. J.
Hartford, Conn.

SCOPE OF SERVICES:—Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply and Distribution Mains in a wide range of diameters as well as Concrete Pipe of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous Lines.

LOCK JOINT
Reinforced Concrete
PRESSURE PIPE

WHAT TYPE DOMESTIC METER DO YOU NEED? . . . . .

We make both the disc and oscillating piston type meters in domestic sizes. We make these two designs so as to better serve our customers.

Our study of varying conditions in water plants throughout the country definitely establishes that a single type of meter is not the answer to all metering problems.

What type domestic meter should you use, disc or piston? In many cases experience or personal preference dictate the choice. Those in doubt are invited to consult with a Pittsburgh-Empire representative.

You can rely on him for an impartial recommendation as to the type of meter best suited to your local water conditions.

PITTSBURGH EQUITABLE METER DIVISION

ROCKWELL MANUFACTURING COMPANY

PITTSBURGH 8, PA.

Atlanta Boston Chicago Houston Kansas City
Los Angeles New York Pittsburgh San Francisco
Seattle Tulsa

This

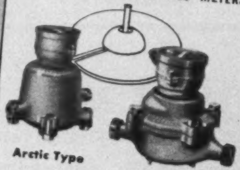
EMPIRE OSCILLATING PISTON METERS

Type 12 **Type 14**

Made with Empire balanced oscillating piston, famous since 1884 for accuracy and durability. Type 12 meter has bronze case with breakable bottom plate to protect interior parts from frost damage. Type 14 is a bronze bottom plate model for warm climates. Sizes ⅝-in., ¾-in., 1-in.

or This

PITTSBURGH NUTATING DISC METERS



Arctic Type **Tropic Type**

The highest quality measuring instruments of this type. Durably constructed to give years of uninterrupted service. Arctic type is protected against damage from freezing by breakable frost bottom. Tropic type has split case, all bronze housing. Sizes ⅝-in., ¾-in., 1-in.

PITTSBURGH-EMPIRE *Water Meters*

BARRETT*
COATINGS

a dependable answer to the problem of protecting Water Pipelines

Barrett* Waterworks Enamels are manufactured specifically to meet the requirements of the water industries:

Barrett Waterworks Enamels neither flow nor sag in temperatures as high as 160°F; nor do they crack in temperatures as low as 20° below zero.

Barrett Waterworks Enamels possess sufficient flexibility to withstand "breathing" of the pipe and deflectional stresses caused by loading of the back-fill.

Barrett Waterworks Enamels, when used for lining, prevent tuberculation or incrustation. Hazen-Williams "C" averages 150. The line capacity is sustained, and power requirements remain uniform.

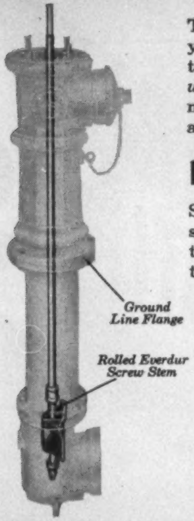
Barrett Waterworks Enamels assure a firmer bond at the interfaces of steel, primer, and enamel—a characteristic of well recognized importance to the water industry.

The Barrett organization will be glad to advise on materials and on application procedures, and to consult with you on any pipe-coating problem.

THE BARRETT DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

*Reg. U. S. Pat. Off.

SERVICE . . . *with a monkey wrench!*



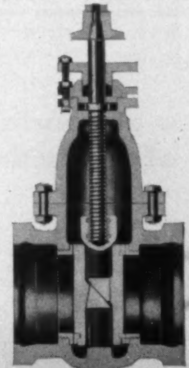
To inspect or service a Ludlow Slide Gate Hydrant you'll need a wrench — that's all. Just take off the top of the hydrant and lift out the stem, *without unscrewing anything below ground*. The entire mechanism, including the gate, bronze wedge nut and drip assembly is attached to the stem.

LUDLOW FIRE HYDRANTS

Shown here is the distinctive Ludlow List No. 90, now serving in thousands of cities and towns. It employs the famous Ludlow Slide Gate principle, and (in addition to easy servicing) offers the following advantages:

- *Quick Water* with least possible shock and pressure loss. Proper shut-off without water hammer.
- *Proper Drainage*, automatically, at lowest point when closed.
- *No Flooding*. Wedge-locked when closed. Accidental breaking will not cause flood. Hydrant head breaks at ground line — is easily replaced without excavation.

LUDLOW AWWA DOUBLE DISC GATE VALVES



The parallel seated, double wedge type slide gate valve, developed and perfected by Ludlow, provides a number of essential benefits.

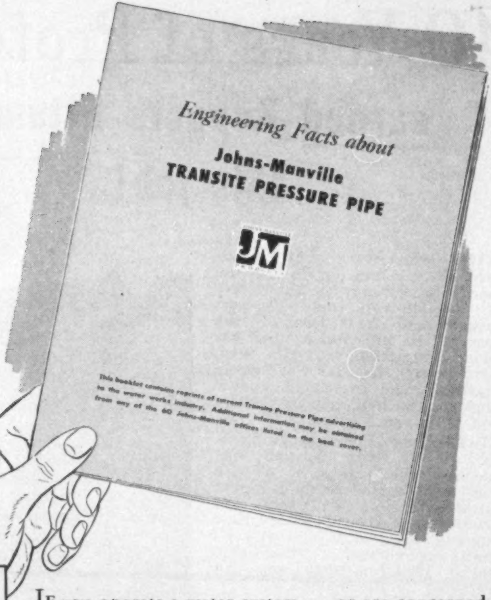
- *Smooth, Positive Operation*. Gates positioned directly opposite ports before wedging, and entirely unwedged before being raised.
- *Positive Closure*. Even after years of service in the open position; flexible-action gates self-adjusting to seats.
- *Simplicity*! Only 2 parts in the wedging mechanism! These are extra heavy with ample reserve strength and wear resistance for years of constant service.

Made in sizes from 2" to 72", N.R.S. and O.S.&Y. with all types of connections. 95-S

TRADE LUDLOW MARK

The LUDLOW VALVE SINCE 1866

MFG·CO·INC·TROY·N·Y·


Engineering Facts about
Johns-Manville
TRANSITE PRESSURE PIPE
JM
This booklet contains reprints of current Transite Pressure Pipe advertising to the water works industry. Additional information may be obtained from any of the 60 Johns-Manville offices listed on the back cover.

SEND FOR THIS DIGEST OF FACTS . . .

SOME OF THE SUBJECTS COVERED IN THIS BOOK:

- Installation Economies
- Carrying Capacity
- The Simplex Coupling
- Making Service Connections
- Resistance to Corrosion —an Index of Long Life
- Case Histories
- Dimensions —and other useful data

IF you operate a water system . . . or are concerned with the design or construction of water works projects you'll find this digest of facts about Johns-Manville Transite* Pressure Pipe helpful.

A compilation of the advertisements in our current "Engineering Facts" series, it presents concise, factual information about Transite's many economic and engineering advantages . . . includes informative case histories that give a new perspective on how this asbestos-cement pipe meets today's requirements for a modern, efficient water carrier.

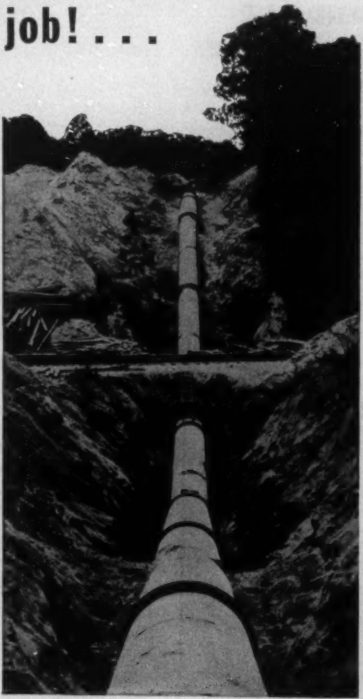
In addition, it contains dimensions and other useful data about Transite Pipe which you'll want for your files. A copy is yours for the asking. Write Johns-Manville, Box 290, New York 16, N. Y.

**Transite is a registered Johns-Manville trade mark*

JOHNS-MANVILLE JM PRODUCTS **Johns-Manville TRANSITE PRESSURE PIPE**

40 Years of Protection

earned Koppers Bitumastic this job! . . .



Springfield's new 48-inch line is shown crossing beneath railroad tracks through 72-inch pipe placed in an open cut. The new steel line, like others in the Springfield system, is protected with Koppers Bitumastic Enamel.

In 1948—when the city of Springfield, Mass., met increasing demands for water with 26,000 feet of new 48-inch line — Koppers Bitumastic® 70-B Enamel was specified as an interior and exterior protective coating. With good reason, too, for Springfield engineers had first-hand knowledge of the long-lasting protection of Koppers Bitumastic.

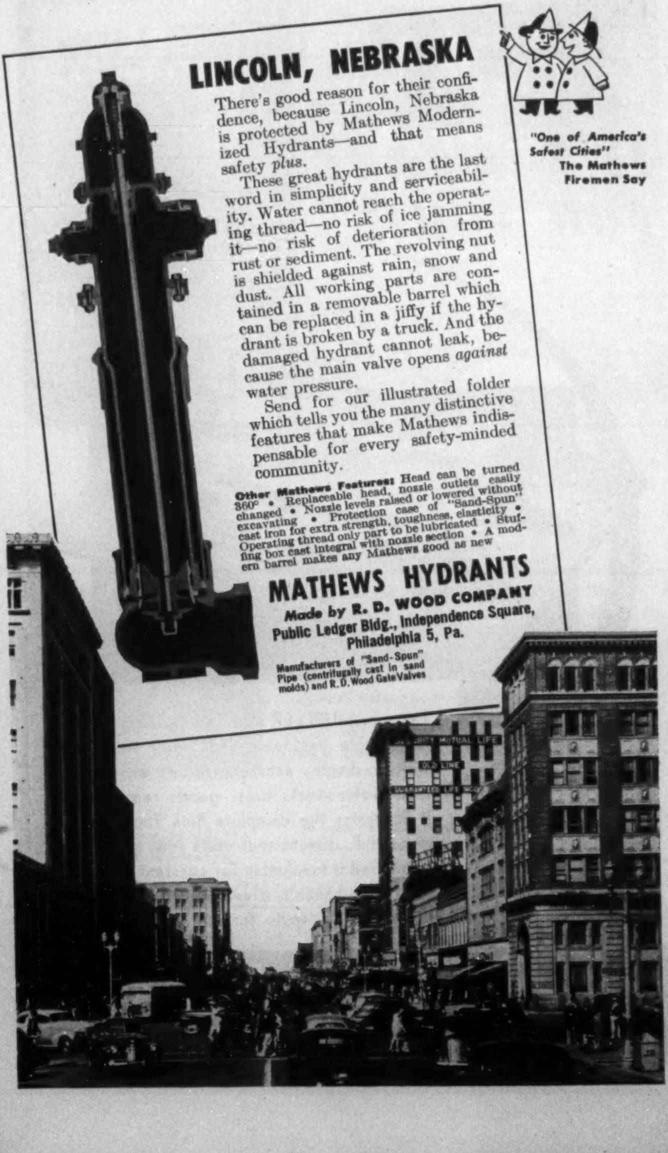
In 1909, when Springfield's Westfield Little River System was started, seven miles of 42-inch line were coated with Koppers Bitumastic. For 40 years, the Bitumastic Coating has kept flow capacity high and guarded the line against corrosion. Other lines, laid in 1929 and 1943, also are protected by Bitumastic.

Inside the pipe, the glass-smooth, high-gloss surface of Koppers Bitumastic Enamel forms a barrier against tuberculation, rust and corrosion. Bitumastic keeps water from touching the underlying steel pipe surfaces . . . protects against the corrosive action of soil chemicals . . . has high electrical resistance. And it won't deteriorate with age.

If you're planning a water or sewage line, turn the coating job over to engineers of Koppers Contract Department. They'll handle it from start to finish, assuring long-lasting protection for the project. Write for complete information on Koppers Contract Service.

KOPPERS **BITUMASTIC ENAMELS**

KOPPERS COMPANY, INC., Dept. 915T, Pittsburgh 19, Pa.



LINCOLN, NEBRASKA

There's good reason for their confidence, because Lincoln, Nebraska is protected by Mathews Modernized Hydrants—and that means safety *plus*.

These great hydrants are the last word in simplicity and serviceability. Water cannot reach the operating thread—no risk of ice jamming it—no risk of deterioration from rust or sediment. The revolving nut is shielded against rain, snow and dust. All working parts are contained in a removable barrel which can be replaced in a jiffy if the hydrant is broken by a truck. And the damaged hydrant cannot leak, because the main valve opens *against* water pressure.

Send for our illustrated folder which tells you the many distinctive features that make Mathews indispensable for every safety-minded community.

Other Mathews Features: Head can be turned 360° • Replaceable head, nozzle outlets easily changed • Nozzle levels raised or lowered without excavating • Protection case of "Sand-Spun" cast iron for extra strength, toughness, elasticity • Operating thread only part to be lubricated • Stuffing box cast integral with nozzle section • A modern barrel makes any Mathews good as new

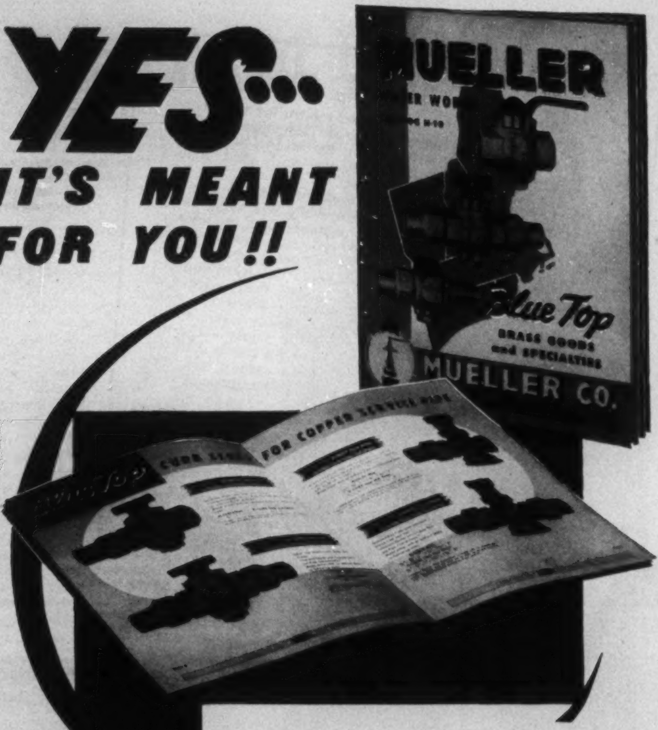
"One of America's Safest Cities" The Mathews Firemen Say

MATHEWS HYDRANTS

***Made by* R. D. WOOD COMPANY**
Public Ledger Bldg., Independence Square,
Philadelphia 5, Pa.

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

YES...
IT'S MEANT
FOR YOU!!

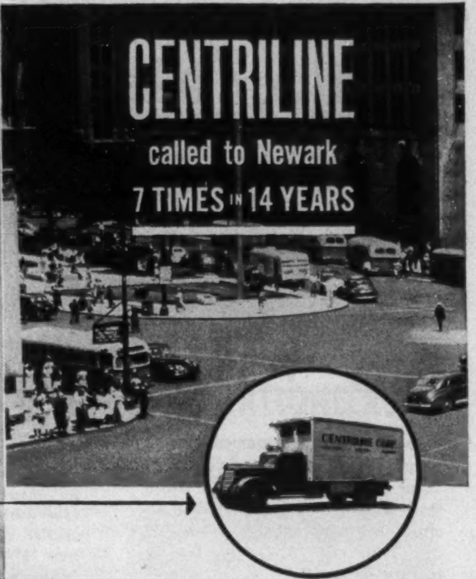

MUELLER
Blue Top
BRASS GOODS
and SPECIALTIES
MUELLER CO.
FOR COPPER SERVICE PIPE

This new MUELLER Blue Top Catalog is meant to provide engineers and water works men with a simple, accurate means of selecting their water works brass goods requirements. It illustrates the complete Blue Top Line and gives full dimensional data on each item. You'll find it invaluable for constant reference, so if you haven't a copy handy right now, don't delay — write for one today.

DEPENDABLE SINCE 1857 FULLY WARRANTED
OUR 91st YEAR

MUELLER CO.
EASTERN SALES OFFICE, 1322 EMPIRE STATE BLDG., N. Y., N. Y.
MAIN OFFICE AND FACTORY ... DECATUR, ILLINOIS
OTHER FACTORIES: *Los Angeles, Cal.; Chattanooga, Tenn.; Sarnia, Ont. Canada*

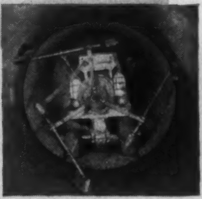
where performance counts . . . count on Centriline



CENTRILINE

called to Newark

7 TIMES IN 14 YEARS



IN 1935 Centriline did its first work for the city of Newark, N. J.—cleaned and lined with cement mortar 27,551 feet of 48" riveted steel pipe. The capacity of this 40-year old pipe was thereby increased 77%—*12% higher than the original capacity—and it has stayed there!*

That may explain why Centriline has been called back again and again to recondition more of Newark's vital water mains. To date, more than 40 miles of these mains have been Centrilined.

If your pipeline investment is under attack by tuberculation and corrosion—if your maintenance and pumping costs are rising—if your mains deliver less water at a time when you need more—call on Centriline. Like Newark, your city will find that it pays!

CENTRILINE
CORPORATION
142 CEDAR STREET
NEW YORK 6, N. Y.

CEMENT MORTAR LININGS FOR WATER MAINS CENTRIFUGALLY APPLIED **In strict conformity with A. W. W. A. Specifications.**

"Badger Meters are the best...when we buy more they will be Badgers"

A waterworks superintendent wrote this, and went on to say: "Our average dead meters for a year was only 7 per month . . . about as low an average as I know of. Your city cannot go wrong buying Badgers".

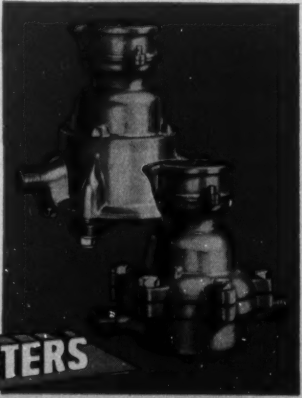
Millions of satisfied users of Badger Meters in over 5000 communities prove that "It Pays to BUY BADGER" . . . unmatched in precision-construction, durable materials, and sustained accuracy, at lowest operating cost.

ANOTHER NEW Badger Chart, No. 696 (Practical floor plan for a large meter repair shop). Available without cost or obligation. WRITE today for this chart.

BADGER METER MFG. CO.
Milwaukee 10, Wisconsin

BRANCH OFFICES:
New York City • Philadelphia • Worcester, Mass. • Savannah, Ga. • Cincinnati • Chicago
Kansas City, Mo. • Waco, Texas
Salt Lake City, Utah • Portland, Ore. • Seattle, Wash. • Los Angeles

You will find a Badger Meter size and type for every waterworks service. Shown here are Model SC-SOT (for warm climates), and Model A-SOT (for cold climates) . . . sizes 5/8" to 1 1/4" . . . other models in sizes up to 12". Write for complete information and prices.



BADGER Water METERS

ACCURACY · LOW-COST MAINTENANCE · DURABILITY · SENSITIVENESS

RCE
35200
In an Emergency
or ANY Time

%PROPORTIONEERS%

Means Clear, Safe Water

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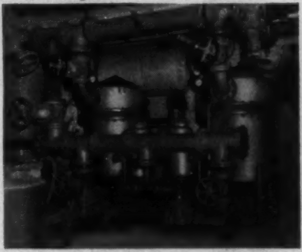

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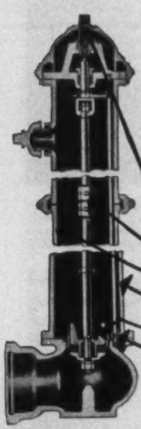

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4 Tapered, frost-proof barrel
5 Compression-type valve.
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SOLVING A DIFFICULT CLARIFICATION PROBLEM AT KENNEBUNK, MAINE

BY M. LANE[1] AND L. G. SMITH[2]

[Read September 16, 1948.]

For many years the towns of Kennebunk, Kennebunkport and Wells have obtained their water supply from the Branch Brook. This is a spring-fed stream, having a low solids content but high color, as shown by the typical analysis in Table 1.

Table 1.—Typical Analysis of Water of Branch Brook.

Ca^{++}	10	HCO_3^-	26
Mg^{++}	6	Cl^-	4
Na^+	24	SO_4^{--}	10
TC	40	TA	40
Color	— 60		
Turbidity	— 20		
Silica	— 20		
pH	— 6.7		

The color is almost entirely due to surface run-off from the woods and fields through which the brook passes. When the brook is frozen over, as it is during a good part of the winter, and there is no run-off, the color of the untreated water is very low—frequently in the range of 5-10 ppm on the APHA color scale.

Until the spring of 1946, the treatment consisted of chlorination, followed by filtration through four horizontal pressure filters. Soda ash was fed into the pump clear-well ahead of the filters, to raise the pH to 7.5-8.0. This had been the treatment for more than 20 years. The color was reduced, and the water was clear, sterile, soft and non-corrosive—a good-quality municipal water. During the spring run-off and after heavy rains the turbidity of the brook water would increase, but it was filterable and the only effect on the plant operation was to increase the frequency of backwashing the filters.

---

[1] Technical Dept., Graver Water Conditioning Co., 216 W. 14th St., New York 11, N. Y.; formerly with Technical Dept., Liquid Conditioning Corp., Linden, N. J.

[2] Superintendent, Kennebunk, Kennebunkport and Wells Water District, 20 Park St., Kennebunk, Me.

Early in 1946, work on the new Portland-to-Boston turnpike reached a point about a mile upstream from the treatment plant. The fill for the turnpike was native clay obtained nearby. Where the turnpike crossed the brook, large areas of this fresh clay were exposed and, as a result, whenever it rained, clay was washed into the brook and, in the space of three hours, the water at the pumping station would be changed from its normal low-turbidity condition to a turbidity measured in the thousands.

This clay turbidity was quite different in nature from the coarse, readily filtered turbidity present heretofore. Much of it was colloidally dispersed. Some idea of the stability of this clay dispersion is given by the fact that a quart sample of the water taken at a time when there was a high concentration of clay would still be opaque after a week of standing and would have about ¼ inch of sediment at the bottom. Needless to say, this colloidal turbidity was not reduced to any appreciable extent by the filters. Most of it passed right through the filters into the mains. Very often customers would draw a glass of muddy water from their taps and, after letting it stand for a few minutes, would have a sediment ⅛-¼ inch deep in the bottom of the glass.

The urgency of the situation was heightened by the fact that the area served by the Kennebunk, Kennebunkport and Wells Water District is summer-resort territory. During the period from June 1 to September 15, the population almost triples and the average daily water consumption increases from about 1 mgd to close to 3 mgd. It was feared that the poor-quality water supply would drive the vacationists away and, in order to clear up this condition as quickly as possible, the firm of Coffin & Richardson, water-supply consultants, was retained by the Water District.

Laboratory Tests

A large sample of the water, taken at a time when the turbidity was high was shipped to the laboratory of the Liquid Conditioning

Corp. Preliminary jar tests revealed that the colloidal clay turbidity stubbornly resisted coagulation with alum and alkali. A summary of the jar-test data is given in Table 2.

These tests were run over a broad range of pH values and with alum dosages ranging from 2 to 6 grains per gal (gpg). Some floc formation was noted, but the floc was light and settled slowly, and the supernatant turbidity was consistently high.

Further tests were run, in which activated silica was used as a coagulant aid. The results (jars no. 8-11, incl.) were startling. With an alum dosage of 2 gpg and a soda-ash dosage of 0.5-1.0 gpg, the addition of 5 ppm of activated silica caused a large, shaggy floc to form, which settled quickly, leaving a clear, colorless supernatant.

Later, after the new plant was put into operation, many more jar tests were run at Kennebunk, both on highly turbid and clear samples of brook water. These tests confirmed the results obtained in the laboratory and, in addition, showed that the activated silica was as effective on the clear, low-turbidity water as it was on the highly turbid water.

The optimum pH range was found to be 5.8-6.2 and the greatest benefit was obtained from the activated silica when it was added about 5 minutes after the alum and soda ash.

PLANT DESIGN

On the basis of these laboratory tests, as well as the many years of experience of the personnel of the Liquid Conditioning Corp. in dealing with coagulation problems, a treatment plant was designed, embodying all of the features which good chemical and engineering practice dictates. It had been hoped that the treatment could be carried out in an upflow Sludge Contact Reactor. However, it was essential to have the plant in operation by the beginning of the summer vacation season, and delivery of motors, speed reducers and other special parts required for the Reactor could not be obtained in the short time available. Consequently, it was decided to install a "conventional" flocculation and settling plant. Figure 1 is a flow diagram of the plant.

Water is pumped up from the brook into the flash mixing tank, which provides 10-20 seconds' detention. Here vigorous and complete mixing trough, which provides for additional mixing. In addition, the plished by means of a high-speed mixer.

TABLE 2.—JAR TESTS ON SAMPLE OF RAW WATER FROM BRANCH BROOK, KENNEBUNK, ME.

Raw Water:
Turbidity — 400 ppm
pH — 6.8

Test Conditions:
Flash Mixing Time (min) — 1.0
Slow " " " —20.
Settling Time " —20.

Jar no.	Grains per gal Alum	Grains per gal Soda ash	Ppm act. silica	pH	[1]Supernatant turbidity (ppm)	[2]Filtered (ppm) Turbidity	[2]Filtered (ppm) Color	Character of floc
1	2	1	0	6.5	30	15-20	20	Small, very slow-settling.
2	2	0.2	0	5.9	25	10	15	" " " " but better than no. 1.
3	2.5	0	0	5.1	30	15-20	20	Same as no. 1.
4	3	0.4	0	5.5	15	5-10	15	Slightly larger and faster-settling than no. 2 but still poor.
5	3	1.0	0	6.0	15	5-10	15	Slightly larger and faster-settling than no. 2 but still poor.
6	3	1.8	0	6.7	30	15	20	Same as no. 1.
7	4	1.3	0	6.0	15	5-10	10	Like numbers 4 and 5. Very small floc. Slow-settling.
8	2	0.2	5	6.1	15	10	5-10	Large, heavy floc formed within 3 min. Settled quickly.
9	2	0.2	10	6.2	15	10	5-10	Large, heavy floc formed within 3 min. Settled quickly.
10	3	0.8	10	6.1	10-15	5—	5	Same as numbers 8 and 9.
11	4	1.1	10	5.9	10	5—	5—	Excellent floc. No detectable turbidity or color in filtered samples.

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[1] After 20-minute settling period.
[2] Filtered through coarse paper.

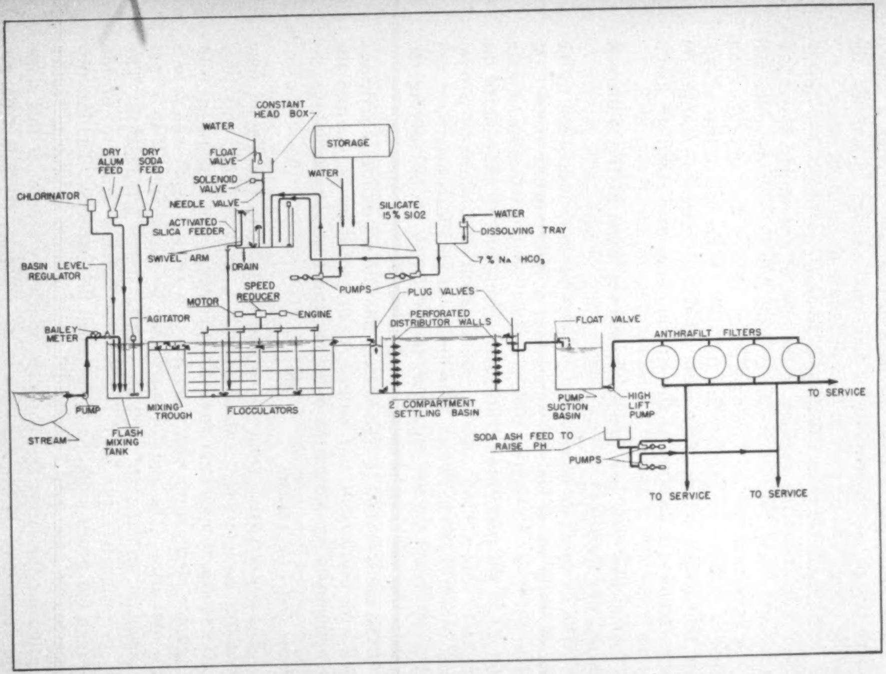
CONSTANT HEAD BOX
WATER
STORAGE
DRY ALUM FEED
DRY SODA FEED
FLOAT VALVE
SOLENOID VALVE
CHLORINATOR
NEEDLE VALVE
WATER
SILICATE 15% SIO2
WATER
DISSOLVING TRAY
ACTIVATED SILICA FEEDER
SWIVEL ARM
DRAIN
7 % Na HCO3
BASIN LEVEL REGULATOR
PUMPS
PLUG VALVES
SPEED REDUCER
MOTOR
ENGINE
PERFORATED DISTRIBUTOR WALLS
FLOAT VALVE
AGITATOR
ANTHRAFILT FILTERS
BAILEY METER
TO SERVICE
PUMP
MIXING TROUGH
FLOCCULATORS
2 COMPARTMENT SETTLING BASIN
PUMP SUCTION BASIN
HIGH LIFT PUMP
STREAM
FLASH MIXING TANK
SODA ASH FEED TO RAISE PH
PUMPS
TO SERVICE
TO SERVICE

FIG. 1.—FLOW DIAGRAM OF COAGULATION AND FILTRATION PLANT OF KENNEBUNK, KENNEBUNKPORT AND WELLS WATER DISTRICT.

(Courtesy of Liquid Conditioning Corp.)

The water passes from the flash mixing tank through a baffled mixing trough, which provides for additional mixing. In addition, the mixing trough can be used in case of failure of the flash mixer.

Chlorine is fed from a Wallace & Tiernan type MASV chlorinator, which proportions the chlorine to the flow of raw water. Pre-chlorination was used, because it aids considerably in reducing color and at the same time aids in forming a larger, heavier floc, since the color tends to stabilize the primary floc particles. It has the further advantage that longer contact time with chlorine is obtained, resulting in more complete utilization of the chlorine and more complete sterilization.

Alum and soda ash are fed from two, Type MOF, Wallace & Tiernan dry feeders.

The feeding rate of chemicals is maintained in proportion to the flow of water at all times, by means of a Bailey orifice meter. At maximum flow, the meter closes a contact every 30 seconds or each time 1,050 gal pass through it. The closing of the relay starts the chemical feeders, which operate for a period determined by a reset timer, which is in the circuit. The dosage of chemicals may be varied either by means of the regulator on the feeder or by varying the duration of "on" time by means of the timer.

The same scheme is used to vary the rate of feeding of activated silica with the flow of raw water. A separate timer is provided for the activated-silica system, in order to furnish greater flexibility.

Mixing and Flocculation

The water passes from the mixing trough into the first of four flocculator compartments, which provide a total "rolling" mix time of 30 minutes at maximum flow. Each compartment is provided with an agitator mechanism, which consists of a vertical shaft with 3 to 5 horizontal arms. The agitator speed may be varied from 2 to 3 rpm by means of an adjustable belt on a Hi-Lo pulley arrangement. The first two compartments have 5 horizontal agitator arms, to provide thorough but gentle agitation of the small floc particles. The last two compartments have only 3 horizontal arms, in order to provide gentler agitation for the larger floc particles, which are present at this stage of the treatment. If the agitation is too vigorous, there is a danger that the floc formed will be broken up.

Activated-Silica System

Activated silica is prepared continually by mixing a sodium-bicarbonate solution with a sodium-silicate solution and diluting the mixture to a concentration of 0.75-1.0% silica. This dilute sol is then aged for 1-2 hours before being added to the water. A number of other activating agents can be used, the most common and cheapest being sulfuric acid. It was decided to use sodium bicarbonate instead of sulfuric acid at this installation, because of the greater ease and safety in handling it.

Figure 2 shows the activated-silica feeding system in detail. A 5% sodium-bicarbonate solution is prepared in the "bicarbonate" tank. A solution containing 15% by weight of silica is prepared in the "silicate" tank, by diluting Philadelphia Quartz "E" brand sodium silicate with the required amount of water. Each time the Bailey meter contactor closes, the two Milton Roy pumps start and the solenoid valve on the dilution-water line opens for a period determined by the reset timer for the activated-silica system. When the period of "on" time has elapsed, the pumps shut off and the solenoid valve closes until the next meter contact is made, whereupon the cycle is repeated.

The volumes of silicate and bicarbonate solutions delivered per meter contact can be set very accurately by adjusting the length of the stroke on the Milton Roy pumps. Also the volume of dilution water is accurately set by means of the needle rate-setting valve. The purpose of the float tank is to maintain a constant head on the dilution-water line, so that exactly the same volume will be delivered each time the solenoid valve opens. Having the dilution water and solutions flow into funnels, as shown in Figure 2, makes checking of the volumes delivered easy for the operators.

The silicate and bicarbonate solutions and dilution water are quickly and thoroughly mixed in the mixing compartment, to form a sol containing 0.9% silica. The sol flows from the mixing to the aging compartment through orifices at the bottom of the partitions separating the two compartments. The velocity through these orifices is very low, so that there is viscous flow from them to the inlet of the decanting pipe, which carries the sol to the point of application. The period of aging may be varied by raising or lowering the decanting pipe.

It was found that the gelation time for a 0.9% sol was greater

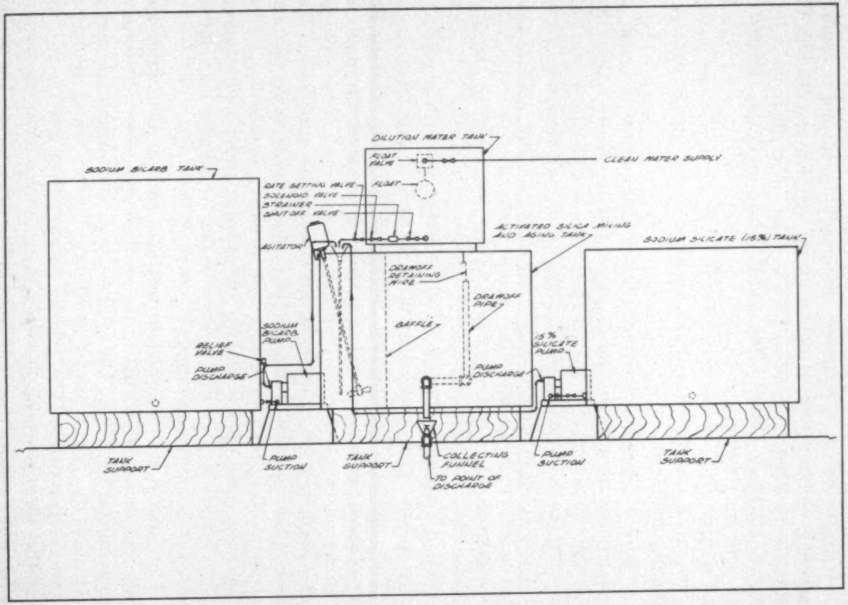
DILUTION WATER TANK
FLOAT VALVE
CLEAN WATER SUPPLY
FLOAT
SODIUM BICARB TANK
RATE SETTING VALVE
SOLENOID VALVE
STRAINER
SHUT OFF VALVE
AGITATOR
ACTIVATED SILICA MIXING AND AGING TANK
SODIUM SILICATE (1.5%) TANK
DRAWOFF RETAINING WIRE
DRAWOFF PIPE
BAFFLE
SODIUM BICARB PUMP
RELIEF VALVE
PUMP DISCHARGE
1.5% SILICATE PUMP
PUMP DISCHARGE
TANK SUPPORT
PUMP SUCTION
TANK SUPPORT
COLLECTING FUNNEL
TO POINT OF DISCHARGE
PUMP SUCTION
TANK SUPPORT

FIG. 2.—ACTIVATED-SILICA FEEDING SYSTEM.

(*Courtesy of Liquid Conditioning Corp.*)

than 24 hours at the average temperature of the sol, which was 60-65°F. Small samples of sol of this strength, prepared and stored in 8-oz. bottles, showed no signs of gelation even after 1 week of standing.

The effect of aging time on the activity of the sol was checked both in jar tests and in the plant, for aging periods ranging from 1 to 6 hours. No difference in the speed of floc formation, size of floc particles or rate of settling was observed with the various sols.

Settling

The water passes from the fourth flocculator compartment into the settling basin, which is split into two sections, each providing a total detention time of 3 hours at maximum flow. Plug valves have been provided at the inlet and outlet ends of the basin, so that all of the water can be passed through one half, while the other half is being cleaned out. The bottom of the basin slopes toward the inner side and toward the outlet end of each basin, so that the accumulated sludge can be drained off easily. A system of sludge removal was considered, during the designing of the basins, which would have permitted removal of the accumulated sludge by means of a header-lateral, perforated-pipe collection system with both basins in operation. This was discarded, however, in favor of the method described above, because it would have increased the initial investment significantly and the variation in demand is such that there are long periods of low demand, during which one basin can be taken out of service for cleaning without increasing the rate excessively on the other.

In order to afford perfectly uniform distribution of the water as it passes through the settling basin, perforated distributor walls are provided at the inlet and outlet ends. The size of the orifices in these walls was chosen to furnish a uniform head loss through them from top to bottom and from side to side. Careful checking of the flow through the basin has shown that this system of distribution is very effective.

Filtration

The settled water flows from the outlet end of the basin into the clear-well, from which it is pumped to service through the existing horizontal pressure filters, which are 8 ft in diameter and 20 ft long.

The sand and gravel fills have been replaced with graded Anthrafilt, since past experience with the use of activated silica has shown that longer filter runs are obtained with Anthrafilt.

Post-Treatment

To raise the pH of the water after filtration, in order to prevent corrosion of the mains and household piping, soda ash is fed in solution by means of a Milton Roy duplex pump. The solution is pumped into the outlet pipe from each filter.

Chlorine and ammonia are also introduced into the high-lift pump clear-well before the filters from the existing equipment. Most of the residual which is introduced by the pre-chlorinator is gone by the time the water reaches the clear-well, so that it is necessary to introduce additional chlorine at this point. Ammonia is fed in order to form chloramines, which persist for a longer time than does a free-chlorine residual.

Flow Control

The water level in the settling basin is automatically maintained within a narrow range by means of a basin-level regulating system, consisting of a Ross piston-operated valve on the raw-water line, which is controlled by a pilot valve. As the level in the basin rises, the pressure on the upper side of the piston increases, throttling the valve and reducing the flow into the plant. In the same way, a drop in the basin level decreases the pressure on the piston and causes the valve to open wider.

OPERATING EXPERIENCE

By the beginning of the summer of 1947, the concrete work had been completed and the pre-chlorinator and alum and soda-ash feeders were installed. The activated-silica system, flocculator drives, flash mixer and Bailey meter had not been received, but the plant was started up without them. Even with this crude method of operation, the quality of the water improved immediately. The color was reduced substantially and, although the high-turbidity condition occurred several times during the summer, the coagulation and settling were sufficiently effective to prevent any substantial amount from passing through the filters.

In September, 1947, the complete plant was put into operation. It was found that the size of the floc particles increased substantially when the flocculator agitators operated and the activated silica was fed.

Initially, sufficient chlorine was fed from the pre-chlorinator to exceed the breakpoint and maintain a free-chlorine residual of about 0.1 ppm Cl_2 after the filters. It was found, however, that the free-chlorine residual attacked the organic coating on the mains and in the storage tank and produced a very disagreeable taste and odor in the water. In order to avoid this, it was necessary to reduce the pre-chlorination dosage so that there was very little residual at the outlet of the settling basin, and to feed sufficient chlorine and ammonia before the filters to maintain a combined chlorine residual of 0.1-0.2 ppm Cl_2.

Because of the "flashy" nature of the brook, it is necessary to run jar tests periodically, in order to determine the optimum pH for treatment. It has also been found that the activated silica is not always required. There are long periods of time when the only treatment required is 2 gpg of alum, 0.5-1.0 gpg of soda ash and a pre-chlorination dosage of 3-4 ppm.

Table 3 shows the influent and effluent quality during a period of extremely high turbidity after a heavy rain-storm.

TABLE 3.—QUALITY OF INFLUENT AND EFFLUENT AFTER A HEAVY RAIN.

	Raw water	Filtered water
Turbidity (ppm)	300-500 (muddy)	5—
Color (ppm)	60-80	5-10
pH	6.3	7.5
Residual chlorine (ppm)	—	0.15

Experience showed that the dosage of activated silica could be reduced to 2-3 ppm when feeding 2 gpg of alum, with excellent floc formation. Higher dosages of activated silica (6-8 ppm) tended to produce a slight but definite colloidal haze in the water, which was present even after filtration.

SUMMARY

The Kennebunk, Kennebunkport and Wells Water District was faced with a very urgent and difficult treatment problem as the result of the exposure of large areas of clay along the brook from which it obtains its water.

A plant was designed to treat 3 mgd, which was in partial operation within 6 months from the start of laboratory tests and which was in full operation within 8 months.

Since the plant was installed, the customers have received a clear, colorless, sterile and non-corrosive water at all times. It has been proven that the plant can handle even the muddiest water, producing the same high-quality effluent as when the brook turbidity is low.

DROUGHT RUNOFF IN NEW ENGLAND‡

BY CHARLES E. KNOX*

[Read December 16, 1948.]

WHAT is a drought? J. C. Hoyt in Water-Supply Paper 680 states: "When in an area that is ordinarily classed as humid natural vegetation becomes desiccated or defoliates unseasonably and crops fail to mature owing to lack of precipitation, or when precipitation is insufficient to meet the needs of established human activities, drought conditions may be said to prevail. Unsatisfactory distribution of precipitation may be as effective a factor in causing a drought as a shortage in the total amount. Temperature and wind may also play an important part, especially in relation to the damage done. In general, however, in the humid and semiarid States serious drought effects do not result unless the annual precipitation is as low as 85 percent of the mean."

Stream flow is the residual of precipitation left after prior demands of evaporation, transpiration, and soil-moisture requirements have been satisfied. In New England, the average evaporation-transpiration loss varies from about 18 to 24 in., which is about half of the average annual precipitation. All except a comparatively small amount of these losses occur during the growing season. During the winter, precipitation in the form of snow is stored on the ground until it melts. If the ground is not frozen some of the snow is melted and replenishes the ground-water table.

As stream flow is a residual of precipitation after other demands have been met, it fluctuates much more widely than precipitation and is related to rainfall only in a most general way. This may be illustrated by the following examples:

> Assume a drainage basin having an average rainfall of 40 in. and a normal evaporation-transpiration loss of 20 in. The net stream flow would be 20 in. or 50% of the precipitation. Now assume a year having 80% of normal precipitation, or 32 in., and normal evaporation-transpiration losses, which would leave

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‡Published by permission of the Director, Geological Survey, U. S. Dept. of the Interior.
*Hydraulic Engineer, U. S. Geological Survey, 939 Post Office Bldg., Boston 9, Mass.

only 12 in. of runoff or only 38% of the precipitation. To make matters worse, assume that the evaporation-transpiration loss was 24 in. instead of the normal 20 in. The net runoff would be 8 in. or 25% of the precipitation.

The above assumed examples illustrate that, although precipitation may be an index of runoff conditions, it should be used with extreme caution in trying to estimate stream flow during past dry years for which no discharge records are available.

Records of low runoff form the basis for design of storage reservoirs for water supply and indicate quantities of water available for run-of-the-river developments. During periods of little or no precipitation, stream flow comes almost entirely from ground water. Reductions in ground-water yield occur in the main when the ground-water table approaches closer and closer to the level at which the water from it enters a stream, spring or well.

Figures 1 and 2 show precipitation by water years and cumulative departures from standard-period mean for Greenville, Me., Plymouth, N. H., Northfield, Vt., Clinton, Mass., and Hartford, Conn. These stations were selected as indexes of precipitation near representative gaging stations. It should be pointed out that the precipitation record is for one point and is not a direct measure of the precipitation over an area. The dashed line on each upper bar graph is the mean annual precipitation for the standard 25-year period, which includes the 1921-1945 water years. The standard-period mean is used to eliminate avoidable errors caused by comparison of unlike periods. The lower graph represents cumulative departure, in inches, from the standard-period mean, starting with zero at the beginning of the standard period.

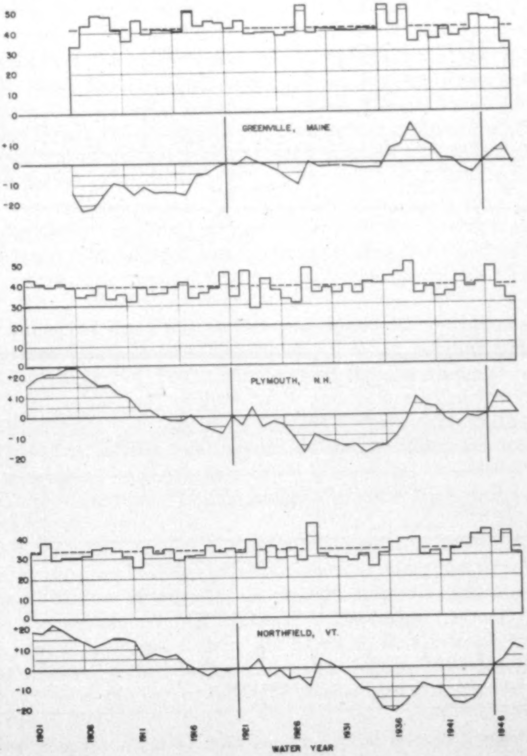
The cumulative departures indicate trends by the slope of the line. A downward slope indicates a dry cycle and an upward slope a wet cycle. The steepness of the slope indicates the magnitude of the deficiency or excess. This is a long-term trend but a short, intense drought can occur during a wet cycle, just as a flood can occur during a dry cycle.

In general, the cumulative lines show the same general pattern. The major exception is that for Greenville, Me., which shows an upward trend, indicating a wet cycle, preceding the standard period.

From the diagrams, it can be seen that all stations show an excess of precipitation for the 1946 water year. Greenville and Northfield

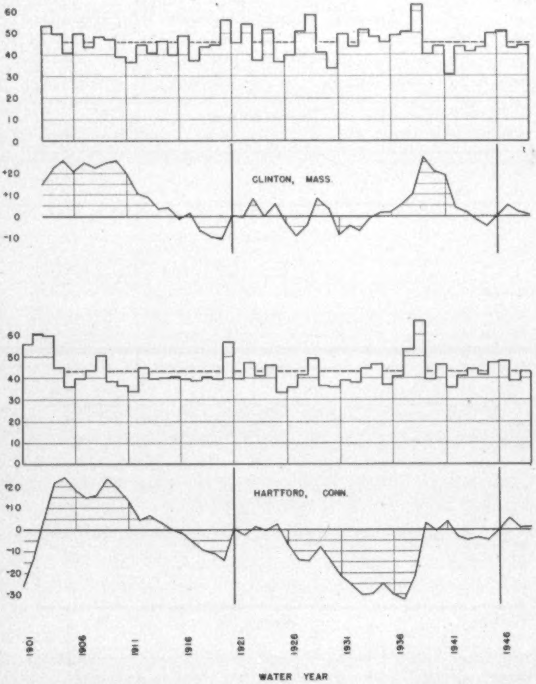
ANNUAL PRECIPITATION, IN INCHES,
AND
CUMULATIVE DEPARTURE FROM MEAN

FIG. I



ANNUAL PRECIPITATION, IN INCHES,
AND
CUMULATIVE DEPARTURE FROM MEAN

FIG. 2



show an excess for 1947. In fact, the Northfield precipitation is one of the highest recorded at that station. Plymouth, Clinton and Hartford all show a slight deficiency for 1947.

In 1948 there was a general deficiency of precipitation, with the greatest deficiences in the northern area. The precipitation for Greenville and Plymouth was near record lows.

Figures 3 and 4 show runoff and cumulative departure from standard-period mean for Piscataquis River near Dover-Foxcroft, Me., Pemigewasset River at Plymouth, N. H., White River at West Hartford, Vt., Ware River at Cold Brook, Mass., Wading River near Norton, Mass., and Quinebaug River at Jewett City, Conn. These stations were selected because they represent unregulated runoff. The dotted portions of the bar graph are estimated records to complete the standard period.

In general, the cumulative lines show the same general pattern. The major exception is that for the Piscataquis River, which shows an upward trend, indicating a wet cycle, preceding the standard period. This exception also showed in the precipitation graph for Greenville, Me.

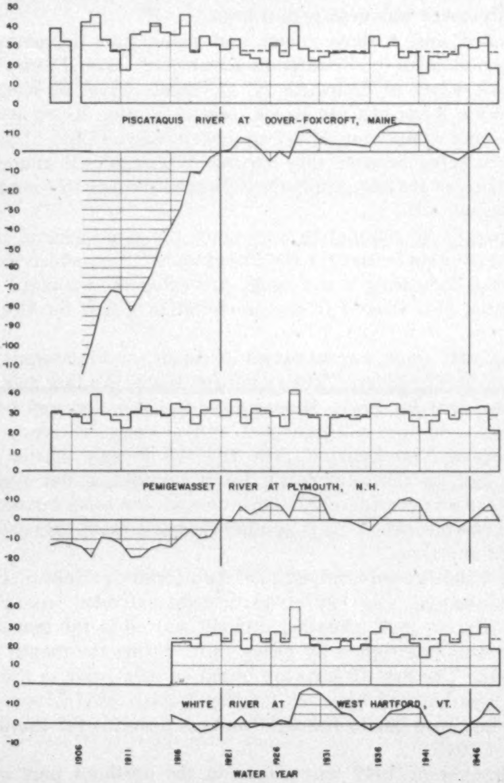
During 1947 there was an excess of runoff for Piscataquis, Pemigewasset and White Rivers. The runoff for Ware, Wading and Quinebaug was deficient for 1947. During 1948 the situation was reversed, with an excess in the southern part and a large deficiency in the northern part of New England. The 1947-48 drought started in August, 1947, but, as the total runoff for the preceding ten months of the water year was considerably above normal, the total for the water year was above normal. This is another demonstration that a drought can occur at any time.

Figure 5 shows comparative runoff data for dry periods of 1, 3 and 6 months' duration. The 1947-1948 drought extended from August, 1947, until March, 1948. Another drought started in the late summer of 1948 but was interrupted by heavy rains during the month of November, 1948. The first 10 bars are based on data prior to the spring of 1948. Cross-hatched bars are for the August, 1947-March, 1948, drought. The single bar to the right of each group is for the drought of the fall of 1948.

The drought of 1947 was severe in the northern part of New England and relatively unimportant in the southern part.

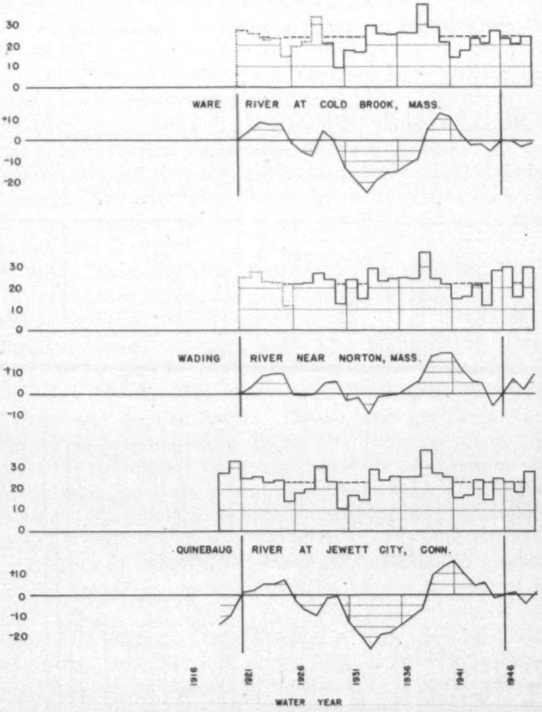
ANNUAL RUNOFF, IN INCHES,
AND
CUMULATIVE DEPARTURE FROM MEAN

FIG. 3



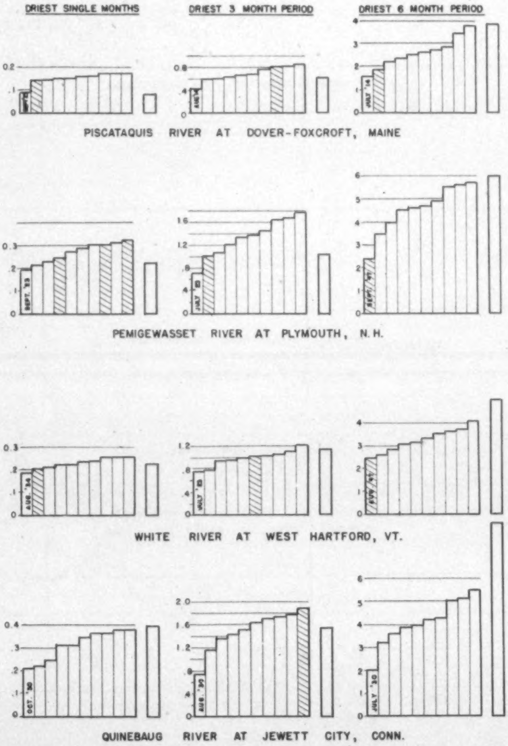
ANNUAL RUNOFF, IN INCHES,
AND
CUMULATIVE DEPARTURE FROM MEAN

FIG. 4



RUNOFF, IN INCHES, DURING
LOW WATER PERIODS

FIG. 5



On Piscataquis River, the minimum monthly runoff was the second lowest recorded. The lowest 3-month runoff was eighth in rank. The lowest 6-month runoff was second in rank.

On the Pemigewasset River, there were 3 different months that ranked in the lowest ten of record. The 3-month runoff ranked second, whereas the 6-month runoff was the lowest of record.

On the White River the lowest-month runoff ranked second, the 3-month runoff sixth, and the 6-month runoff was the lowest of record.

In general, the 1947 drought in northern New England was the worst experienced over a 6-month period.

The 1948 drought was of a shorter duration but was more severe than that of 1947 in Maine and New Hampshire.

On Piscataquis River, the minimum monthly runoff was the lowest on record. The runoff for the lowest three months ranks fourth. On Pemigewasset River, the minimum monthly runoff ranks third and the 3-month runoff third.

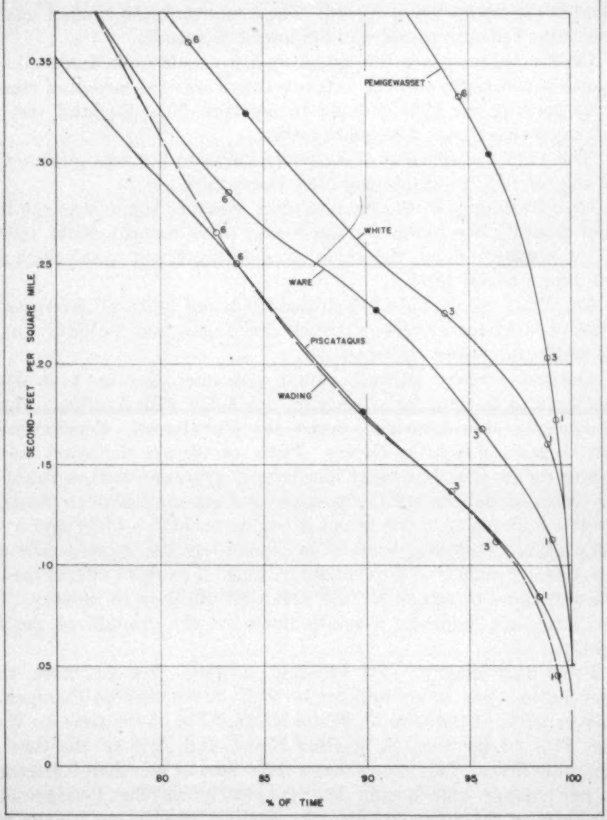
On White River, the 1948 drought was not quite as severe as on the above-mentioned rivers, although the single- and 3-month runoffs rank within the lowest ten of record.

Duration curves indicate runoff characteristics of a drainage basin and can be used for comparing one basin with another. Figure 6 shows the flow-duration curves for Piscataquis, Pemigewasset, White, Ware and Wading Rivers. These curves are the lower end of duration curves based on daily discharges. Duration curves based on many years of records are fairly stable and are used here to illustrate the relative intensity of the recent droughts on both a yield and a frequency basis. The yield scale is in second-feet per square mile and the frequency scale is in percentage of time. The open circles are for the lowest flows of record for the indicated duration in months. The solid circles are minimum 3-month flows for the drought of the fall of 1948.

From this diagram, for example, a daily flow of more than 0.3 second-foot per square mile occurs 96% of the time on Pemigewasset River, 86% of the time on White River, 82% of the time on Ware River, 81% of the time on Wading River, and 79% of the time on Piscataquis River. This shows that a daily flow of less than 0.3 second-foot per square mile occurs less frequently on the Pemigewasset River than on the other streams. As monthly discharges are the sum

FLOW-DURATION CURVES

FIG. 6



of daily flows, it follows that monthly flows on Pemigewasset River should be higher than those on the other rivers. Considering the drought of 1948, we see that the yield of Pemigewasset River was less than that for White River but was greater than that for Ware River and Piscataquis River. However, the flow-duration curves indicate that the frequency of the yield of Pemigewasset River was considerably lower than that for the other streams. In other words, the drought on Pemigewasset River was more unusual than that on the other rivers, even though the flow was lower on the others.

Runoff characteristics vary greatly for different streams throughout New England. In the planning of any water supply on a stream, it is recommended that discharge records for that stream be used in the design. The Geological Survey does not have records on many of the smaller streams, but our gaging stations are well distributed throughout the area and sufficient data are available so that a close approximation can be made of the yield for ungaged streams throughout the region. Drought studies are based on analysis of low flows recorded at gaging stations operated in the region.

THE CASE FOR WATER WITCHING

BY LINCOLN W. RYDER*

[*Read December 16, 1948.*]

THE recent article by Kenneth Roberts in *Life* magazine (October 4, 1948) reveals the persistent belief by many in the potency of a forked stick or similar device in the hands of a water witcher for finding water. With the interest in the location and exploration of ground-water supplies aroused by the excellent paper presented to this Association last September by Daniel Linehan, S.J., and Scott Keith,‡ and because of the extreme importance to many of you of that subject, a discussion of this ancient and, in some circles, common method should be of interest to the up-to-date water-works man.

The interest of the hard-headed financial world is shown by an article in Barron's magazine in 1935, "S.E.C. Probes Doodle Bug Theory," and that of the oil and natural-gas industry by an article entitled "Superstition, Credulity and Psychic Nonsense Still Play a Busy Part in Hunt for Oil and Gas." Electrical engineers added to the controversy in 1942 with an article entitled "Is There an Electrical Basis for Water Divining?"

No article on water witching was found in the Journals of the New England Water Works Association or in the Transactions of the American Society of Civil Engineers. However, the British Institution of Water Engineers in its May, 1947, Journal had a question-and-answer type of discussion of the subject, and the American Water Works Association printed two papers on the subject in 1907 and 1931.

The A.W.W.A. paper of 1907, entitled "Dowsing", suggested that the explanation for detection of water by such methods lay in the sensitivity of the human body to the shadow effect of underground water on radioactivity from rocks below the water body. The 1931 paper in the A.W.W.A. Journal, "Water Witching", tells of the retaining of the services of a water witch in locating an additional supply in Iowa and presents the explanation that the forked stick completes an electric circuit.

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*Assistant Engineer, Metcalf & Eddy, 20 Providence St., Boston (16), Mass.

‡This JOURNAL, 63: 1, 76, March, 1949.

In an issue of Water Works Engineering in 1944, there was an article indicating that the water diviner was recognized and employed by the Royal Engineers of the British Army, although saying that location of water by such a method was a psychic phenomenon. Incidentally, diviners were employed by the French Army in the first World War, in an effort of the French to be superior to the enemy in subterranean research.

In 1931, a 308-page book on "Water Diviners and Their Methods" by Mager was published in London and, in 1940, a 450-page textbook on "Physics of the Divining Rod" by Maby and Franklin was also published in London.

The practice of referring questions of the whereabouts of hidden objects, such as water sources, treasures, ore deposits and boundary monuments, to the divining rod in the hands of an oracle or a magician developed before recorded history and is mentioned in many of the earliest writings. The Bible has many references to finding water by this method, relating that Moses, among others, used it with complete success.

The art was practiced by the Greeks and Romans and by the Chinese. The present high-sounding name of "rhabdomancy" or "rod divining", as applied to the art of seeking for springs, well sites, precious metals and other things concealed in the earth by means of a divining rod, comes from the Greek language.

In early times, the miraculous powers of the rod, often in the form of an arrow, a stave, a sceptre or a bundle of sticks, were not limited to finding objects in the earth but extended to searching out the secret guilt in the hearts of men, to curing disease, to bestowing immunity from disease and ill fortune, to analyzing character, to pointing out murderers in crowds of worshippers at churches and to tracing stolen or strayed animals. The rod of authority of the god, Mercury (or Hermes), the "caduceus" with snakes entwined about it, was a divining rod and is now the symbol for the medical profession, worn by the Army Medical Corps.

The specialization of the rod to its use for the location of mineral deposits and water sources came about in the middle of the sixteenth century, among miners in the Harz region of Germany, and was spread by them in their emigration to Cornwall in England.

At once the angry controversy arose as to the validity of the method. Since then, its power has been attributed to sympathetic affinity, to motor automatism, to the God-given faculty of the operator, to pixies, to vibrations, radiations, emanations and effluvia of many physical and chemical principles, and to demoniac influence. During the persecutions of people for witchcraft, in the early sixteen hundreds, the water diviner customarily had his instrument duly baptized in a church at the same time as a new-born baby and with the baby's name, to avoid the stigma of connection with Satan and his works.

As scientific knowledge of the principles of electricity and magnetism, and the theory of radiant energy became more widespread, the many explanations of the working of the divining rod were a mixed-up jumble of scientific terminology in those fields. With the increase in published information on psychology and the working of the human mind, and with experiments on extrasensory perception, the explanations have adopted the terminology of the psychologist. An example is the use of "motor automatism", a reflex action excited by stimulus upon the dowser's mind, like the homing instinct in pigeons, below the level of conscious perception. Apropos of this is the comment in the Encyclopedia Britannica that "the best dowsers have generally been more or less illiterate men, engaged in some humble vocation."

Many kinds of "instruments" have been used for water divining, in addition to the familiar forked stick of witch-hazel. The rod may be of many kinds of wood, some dowsers preferring species growing near water, such as willow and hazel, and others choosing apple or peach. Rods made of materials such as iron, copper, horn, ivory and whalebone have been used, as well as a common implement such as a buggy whip, sieve, ring or corset stays. Other apparatus is used, such as a pendulum, a pole balanced horizontally on the forefingers, and a Bible and key tied together.

Mager's apparatus is described by himself (page 5) to be a "galvanometric indicator of moving underground water" and "consists of a long weakly magnetized needle moving on a pivot above a cylindrical mass of soft iron. When this apparatus is brought into the flux of force which lies above every stream of underground water, the lines of force enter the mass of soft iron and in their tumultuous passage cause the excited needle to describe large oscillations."

Further evidence of a rather widespread belief in the efficacy of water witching for the location of underground water is the great number of inquiries received annually by the U. S. Geological Survey. In 1914 the Survey published a 60-page discussion of the subject with a bibliography of almost 600 entries. The growth of interest is shown by the fact that 98 references were for the period 1560 to 1699, 92 in the century from 1700 to 1799, 146 in the next century from 1800 to 1899, 128 in the decade 1900 to 1909, and 95 in the 5-year period 1910 to 1914.

The Industrial Arts Index carried several entries each year up to the second World War under the heading "divining rod" and, in several issues, has made cross-index entries to that heading from the word "rhabdomancy."

In 1932, a series of International Congresses of Diviners was instituted under the auspices of the Italian government, the first such meeting being held in Verona, Italy, attended by several hundred students and diviners—mostly Italian, German, Austrian and French university professors. This congress was followed by one in Germany in the next year. The practice was given legal status by the Italian government in 1932, by the resolution of the congress requiring a diploma for the practice of water divination.

The writer has recently met a water locator claiming to be able not only to locate ground water but to predict the depth, the width of the water channel and the flow from the well, before any drilling is done. His "instrument", from the several descriptions given by those watching him work, is contained in a single, heavy black box about the size of a suitcase.

Many tests have been conducted under scientific auspices, some proving to the learned body conducting the test that there is validity in the claims of the dowser and others proving that the practice is absurd, without scientific foundation and utterly worthless. The reader may draw his own conclusions.

DISCUSSION

ARTHUR C. KING (Taunton, Mass.). Perhaps some of you have had experiences with water witching which might be interesting for us to hear.

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Thomas R. Camp (Boston, Mass.). I believe Mr. Enslow had an experience which he might relate.

Linn H. Enslow (New York, N. Y.). The experience which I have had with water witching is rather unique, I think. I have tried it myself and have never been able to get any response to any kind of a switch with which I have experimented. But I did see a case one time—had personal contact with it, so that I know it is true—where an illiterate man, as the speaker has said, did locate water mains with some sort of a switch—there was not any question about it—and he had no knowledge whatever on which side of the street or road that water main was. Then, after he had located this water main, they took him down to the pumping station, where there was a network of mains under the lawn. Well, the switch went crazy—there was not any doubt about it. That poor fellow had to give up. But it was rather a mean trick.

Now, that is my experience with water witching. But I want to say this: I don't think you can fool all the people all the time. The British seem to have high regard for certain individuals who are called diviners.

A Member. I am very much interested in this subject. I had an experience during the first World War which was rather unique and, if anyone in this room was in the Balloon Service, I think that they will bear me out. I had occasion several times to fly in a free balloon over the Ohio River. We were located at Camp Knox and, when we approached the Ohio River traveling in a northerly direction at about 1,400 ft., it was impossible for us to cross the river until we had ascended to about 1,800 ft. That meant that we had to throw out a lot of ballast. On one occasion, when we approached the river at that altitude, we were very much interested to see whether the river had a current that was causing the balloon to follow it. We followed the river nearly to the bridge in Louisville, which crosses to the other side of the river, and, where there is a sharp bend in the river, we left it.

I talked with some of the fellows that had been located in St. Louis at the Missouri Aeronautic Society and they told me that, in order to cross the river at St. Louis, they had to go up to 2,000 ft. To my mind there is a bigger drag, which causes an air current to flow with the river. That has been my own experience.

To come back to water witching—we have two people in our town who can locate wells. I have worked on wells that they have located. They will locate them to within approximately 5-foot depths. I will not say they will tell the exact number of feet, but they will locate a well within 5 ft.

James D. Halwartz (Winchester, Mass.) During the course of this last war I was with the Water Supply in northern Italy, in the northern Apennine Mountains. The frequency of wells and rivers in that part of the country was such that we had to truck water up to the Apennine divisions. A well-drilling rig in our battalion was brought up to drill some wells. They ran around in some of the toughest country I have ever seen and had no luck. Some of the men in the Fifth Army Headquarters heard about the water diviners who worked for the British Eighth Army. They sent one over. He was an engineer, a corporal, who came from New Zealand. He had worked with the British Eighth Army and, if any of you gentlemen have read the book, "Pipe Line in Egypt", you have perhaps seen his name. He was supposed to have had very good luck in the desert. But we used him for three weeks in the mountains and he ran up and down hill, going into farmhouses, and never located a well for us.

The officer in command of the section I worked with was a geologist. He watched the diviner every day in those three weeks and it was his opinion that the man watched the formation of the ground. I am not a geologist and those things do not mean anything to me. But the captain said that this man would follow the formation of the ground and, where you would naturally expect water to form a pocket, that stick would go down. However, if we drilled there, there was no water. We decided to play a trick, similar to the one Mr. Enslow mentioned. We had a big yard, and we had several men go to work and lay pipe all over that yard. They made a grid system. We then hooked up a pump and started pumping water, and then asked the man to come down and test it. He came and his stick would go down. We would go along and kick a gate valve—one of the quick-acting valves we had on the line—and immediately the stick would go down, but no water would be going through that pipe. We agreed that diviners were of no use whatsoever.

Mr. King. That seems to be the worst of it. Once in a while it seems to work and then, at other times, it does not seem to work at all.

TASTE AND ODOR CONTROL

BY E. A. SIGWORTH*

[*Read at Chemists' Round Table, January 20, 1949.*]

TASTES and odors in water supplies are generally due to trade wastes, decomposing vegetation or algae. Trade wastes occur relatively infrequently in a water supply but, when they do exist, can cause considerable difficulty.

The New England territory is blessed for the most part with high-quality sources of water supplies, where trade wastes are of little moment. Furthermore, New England supplies are for the most part relatively deep, so that decomposing vegetation is usually a relatively minor item. Algae, on the other hand, can readily develop in any water supply, since all that is essential for their growth is sufficient food, which is present in almost all waters, proper temperature of the water and usually sunlight. Most of the offensive algae will thrive abundantly on nitrogen compounds, which find their way into water supplies from fertile soil or from sources of pollution.

PREVENTION

The old saying that "an ounce of prevention is worth a pound of cure" is frequently quite applicable to water supplies facing a taste and odor problem. From the viewpoint of trade wastes, numerous water supplies have adopted a watershed-control program whereby, through coöperation with industries and towns within the watershed area, they have been able to reduce appreciably the pollution load in their water supply. Adoption of such a program can frequently lead to considerable headaches, particularly when it is necessary to approach a firm that has been doing business for a good number of years. When such a firm is approached on discharging objectionable wastes into a stream, it is quite natural for the firm, after having followed a similar practice for such a long period of years, to wonder why it should suddenly be condemned at this time. Many water supplies are coming to realize that industry is not the iron horse that will override everyone.

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*Industrial Chemical Sales Division, West Virginia Pulp & Paper Co., 230 Park Ave., New York 17, N. Y.

In fact, many industries, when properly approached, have gone to great extremes to coöperate with water departments, where their wastes might be troublesome.

From the viewpoint of algae, the use of copper sulfate as a preventive treatment is well known to all water-works men. Dr. Silvey of North Texas State Teachers College, Denton, Tex., has offered some very interesting observations over the past few years. In his early years as consultant for water departments in the Texas area, his experiences in using copper sulfate led him to the conclusion that the treatment was not only expensive but resulted in only a temporary control. He frequently found that blooms would return after a short period of time, with an even denser algae population than before. This caused him to search out other methods of control.

According to the limnologists, reservoirs consist of a complex community of living plants and animals. The degree of life in the reservoir will depend upon the type of soil within the reservoir itself and also the type of soil within the drainage area. Dr. Silvey reports that fertile land will give rise to prolific growths of both flora and fauna and has proposed that algae control be accomplished by depending on natural biological processes. Biologists should be employed to keep reservoirs in balance as much as possible.

Some understanding of the life cycle in water is essential. In many ways life in water is similar to that existing on the earth's surface. Plants in the water serve as food for animals or, upon dying and decaying, serve as fertilizers for other plants. Animals, of course, depend upon plants and frequently smaller animals for their food. Also in water there is another dependence of animals and plants, in that animals must depend upon oxygen, giving off carbon dioxide, whereas plants must depend on carbon dioxide, giving off oxygen.

According to Dr. Silvey, a proper control within a reservoir would provide for an even balance, so that no one form of animals or plants would become excessive. Dr. Silvey has suggested that reservoirs for impounded water supplies should preferably be constructed on infertile or submarginal land.

After the reservoir has been well established with plant life, the first step involves stocking with fish, the type apparently depending upon the turbidity of the water. For muddy waters he suggests catfish, white crappie and hickory shad, while for clear waters he recommends such fish as black bass, black crappie and hickory shad.

Life in a new reservoir will start to become complex, due to various types of plant growth and due to birds and insects, which will be attracted to the body of water, bringing in various types of insects and unicellular animals. Ultimately varieties of worms will be established in the bottom deposits. Fish placed in the reservoir will then complete the complex life in the body of water. The number of fish to be added per acre will depend upon the fertility, which in turn depends upon the fertility of the land, both under water and on the watershed.

Algae in the water serve as a food for the fish, as well as for the insects and smaller animals. In addition to the algae, fish will feed on the smaller animal forms, which in turn have fed on the algae.

The average life of fish in Texas water supplies is somewhat less than two years. A study of the water supplies in Texas under the supervision of Dr. Silvey developed the fact that fish, for the most part, start to die in October and deaths continue at a fairly rapid rate up to March. In the case of the colder climates of New England, it is possible that this period of fish mortality might extend over a somewhat longer period of time. As these fish die, they settle to the bottom of the reservoir, where decomposition takes place and the products of decomposition become food for algae. Based on the experiences in Texas waters, the period of fish mortality has been considered a possible explanation for algae blooms which predominate in November and April.

Dr. Silvey has stressed the desirability of maintaining an equitable balance between the plant life on one side and the animal population on the other. Over-population of a reservoir by fish in relation to the amount of food available has been found to result in mature fish extremely small in size. In some cases they are only a matter of three or four inches long. Therefore, Dr. Silvey has suggested that permitting fishermen on reservoirs and lakes would have a favorable influence on maintaining the proper balance between plant and animal life, and would allow fish upon maturity to be of reasonable size. Furthermore, this removal of fish is proposed as a means of reducing the number of deaths of fish within the reservoir, which subsequently lead, after decomposition, to algae blooms.

More recent investigations by Dr. Silvey have led him to the conclusion that odors normally attributed to decomposition of algae are actually due to other organisms in the water. He has found that, when algae are killed by copper sulfate, these other organisms, which are closely associated to the algae, are given free reign in the water and multiply quite rapidly, this process giving rise to the tastes and odors which are usually attributed to the dead algae. Such organisms have been isolated and are now in the process of being studied for identification. These developments offer a new approach to the problem of tastes and odors which we have considered due to algae and are certainly worthy of due consideration and more thorough study.

Correction of Tastes and Odors

No matter how carefully a supply may be supervised, there is always the possibility of a taste and odor condition's getting out of bounds and requiring some corrective treatment. Prior to 1929, the only methods in common practice were aeration and chloramine treatment. Chlorination, of course, was practiced but application was, for the most part, at the marginal point and most frequently resulted in aggravation of the taste and odor condition. Chloramines were beneficial in preventing the aggravation of odors by marginal chlorination and in some cases actually resulted in a reduction of the odor concentration. However, with the advent of powdered activated carbon, the water personnel actually received the first positive means of taste and odor control. That there was a crying need for such a material is evidenced by the wide and almost immediate acceptance of activated carbon in the water-works field. Up to the present time there have been well over 1,200 water plants throughout this country and Canada where activated carbon has been used as a taste-and-odor-control measure.

More recently, with greater knowledge of chlorination reactions, the use of chlorine at higher dosages has received wider publicity as a taste-and-odor-control measure. For quite some time this procedure was called "breakpoint chlorination" but more recently there has been a change to the term "free-residual chlorination." Essentially, this involves application of chlorine in sufficient concentration to oxidize completely all free or combined ammonia existing in the water supply and still leave a chlorine residual. Any chlorination to a lesser point would give residuals as combined chlorine, instead of as free chlorine.

Chlorine dioxide is the most recent addition to the field as a means of controlling tastes and odors. The benefits of this material for taste and odor control are attributed to its higher oxidizing potential in burning up the compounds responsible for tastes and odors. In addition to these methods, I should be remiss if I did not mention the possibilities of ozone for taste and odor control, and also bleaching clay.

It must, therefore, be realized that the water-works fraternity now has available a great number of possible corrective measures for controlling that still troublesome problem of tastes and odors in the water supply.

During the past ten years our company has, in so far as possible, followed the practice of sending research men into the water-plant laboratories, in order to study existing taste and odor problems and to try and recommend the most favorable treatment or combination of treatments which will give the desired degree of palatability. In order to accomplish this, it was first necessary to have a means of determining the odor concentration and, very fortunately, such a tool was available in the threshold-odor test. Unfortunately, many criticisms have been directed against this test, because of its lack of sensitivity and lack of uniform results when different observers conduct the tests. In spite of these criticisms, the threshold-odor test, at least at the present time, is the only means available for evaluating intensities of the wide variety of odors likely to be present in a water supply. Also to commend this test is the fact that the results are determined by an individual's sense of smell, which is exactly the same means that the consumer takes to determine when a water is unpalatable and to register consumer complaints.

Threshold-odor results are reliable when obtained by an experienced observer. It usually requires only a relatively short period of time for almost any individual to develop sufficient accuracy for dependable results. Our research men in travelling throughout the country have explained and demonstrated the threshold-odor test to operating personnel and chemists in water-treatment plants, with the result that the test has received much wider acceptance and use in recent years. It should be emphasized that nearly all individuals have a sufficiently good sense of smell to be able to conduct this test.

The primary consideration of an individual for the threshold-odor test is not so much that he have a super-sensitive sense of smell, but more that his sense of smell should be consistent or uniform. The average consumer in smelling water will base his judgment on a cold or, at the most, lukewarm sample of water. On the other hand, the observer in the water plant takes advantage of the fact that odors are more intense in hot water and therefore conducts his tests on hot water samples. Thus the observer in the plant can detect odors which would not normally be noticeable to the most super-sensitive of his customers.

The basic fundamentals for the threshold-odor test provide for a comparison of odorous samples with odor-free water. Odor-free water is readily obtained simply by passing tap water through a bed of granular activated carbon. This odor-free water is subsequently used as a check for the observer and also for dilution of the odorous sample of water to various concentrations, in order to determine threshold-odor value of the water.

Dilutions are made according to the odor intensity of the sample to be evaluated. The following table gives suggestions for dilutions of water ranging from mild to very strong:

Faint odor	Fairly strong odor	Very strong odor	Very intense odor
200 ml	55 ml	15 ml	4.0 ml
145	40	11	2.9
105	30	8	2.0
75	20	6	1.5
55	15	4	1.0

It will be noted from the table that five dilutions would be made. In addition to these five samples there would be one flask containing 100% odor-free water. All of these samples are then heated to the same temperature for observation and it is our experience that a temperature of 60°C. is very satisfactory. After all samples have reached this temperature, the flask containing the odor-free water is placed to one side. The other flasks are then turned so that any numbers on the flasks cannot be seen by the observer. Samples are mixed up and the observer then proceeds to smell the samples, starting off by first smelling the odor-free water sample and then one of the diluted samples. He continues his observations, each time smelling of the odor-free water before observing one of the diluted samples. It is the observer's duty to distingush only the presence of, or absence of, odors in the diluted samples. For example, he will place all those in which he observes an odor to the left and all those in which he does not observe an odor will be placed to the right. After this division is made, the lowest dilution of those in which an odor was detected will indicate the threshold dilution of the water. The threshold-odor value can be determined by dividing the number of ml of the odorous sample into 200. However, conversion tables are usually made available for ready determination of the threshold-odor number.

After obtaining the threshold-odor number of the water, it is necessary to correlate the result to the palatability. In this connection it must be realized that odorous compounds in water can be present in such small concentrations that they will not be perceptible even in conducting threshold-odor tests on samples of hot water. Also, even higher quantities of odorous compounds can be present in cold water samples without being detectable. Therefore, it is natural that some, particular, hot threshold-odor number can be assigned to water which would be palatable at the temperature at which water is usually drunk by the consumer. In order to determine this palatability level, samples of filtered, or preferably tap, water are diluted to different degrees with odor-free water, until the palatability level is reached. Samples of such dilutions should be observed by three or four individuals and such observations should be on a blindfold basis. Usually the average of three or four observers will be a reasonable measure of palatability. Once the dilution for palatability has been determined, this same dilution should be evaluated for threshold-odor number on heated samples. The threshold odor obtained will thus be the maximum odor level for which the operator should strive, in order to deliver a palatable water to the consumer at all times.

Our research men in visiting a water plant will first develop a case history of the odor from the raw water and on through the various treatments, during passage through the purification process. Odor tests will also occasionally be conducted on the tap water and also the threshold odor of palatability will be determined. Let us take a few individual cases, in order to try to demonstrate the effect of various treatments on the odor intensity.

CASE A.

This is a water plant delivering approximately 36 mgd. Raw water taken from the Missouri River has odor concentration of 30 threshold-odor units, with a muddy, earthy, to slightly musty odor. This water, being extremely turbid, is first passed into primary settling basins, where the odor characteristics change to a musty odor without any diminution of intensity. Water then passes to a mixing basin, where alum and lime are added, and thence to a settling basin, where the odor was characterized as musty to earthy with an intensity of 20 threshold-odor units. The water then passes through a second mixing basin, where alum is again applied and, after settling, the threshold odor was found to be 18 with a musty to earthy odor. Water then passes into another settling basin, where chlorine was applied at a marginal dosage, and, as the water entered the filters, it had an intensity of 21 threshold-odor units with a chlorinous to chlorox odor. After filtration, odor intensity was 22 threshold-odor units with a chlorinous to musty characteristic. Ammonia and chlorine were applied as a post-treatment to a residual of 0.75 ppm. The odor value of this water was found to be 18, with a chlorinous to musty odor. A sample of tap water obtained in the town was first de-chlorinated and, upon testing, showed an odor intensity of 17 threshold-odor units, with a sour musty odor. This same tap water, diluted with various amounts of odor-free water, showed that a threshold value of 7 would be palatable.

Evaluation at this plant showed that the application of activated carbon to the second mixing basin would give optimum results. This point of application would also be advantageous from the viewpoint of the influence of carbon on chlorine and vice versa. It is well known that activated carbon has a tendency to absorb chlorine, so that application of activated carbon and chlorine at the same points may not only reduce the efficiency of the chlorine by reducing its concentration but may also reduce the effectiveness of the activated carbon for adsorption of odors. Therefore, where at all practicable, it is advisable to keep the points of application of activated carbon and chlorine separated. Occasionally odorous compounds which have been chlorinated are found to be more difficult to remove by adsorption with activated carbon, but in this particular case it was found that chlorine had no effect on the efficiency of activated carbon.

CASE B.

This plant delivers approximately 3 mgd of water. Raw water is obtained from an impounded reservoir with a musty, grassy, woody odor of 10 threshold-odor units. Odors at this plant were due to algae and an analysis of the water showed the following organisms present:

Tabellaria
Melosira
Cymbella
Synedra

Raw water passes through a mixing basin, where alum and chlorine are applied, the latter at a dosage of 1.8 to 2.4 ppm. After settling, the water still had an odor intensity of 10 threshold-odor units and the same intensity after filtration. In the clear-well ammonia and chlorine are applied in a ratio of 1:3 and the odor intensity was still 10 threshold-odor units. Palatability level, determined by dilution of the tap water, was found to be 5 threshold-odor units. When activated carbon was applied to the filter influent at a dosage of 34 lb per mil gal, the filter effluent showed threshold-odor values of 4 to 5, which were well within palatability limits. It might be worthy of mention that laboratory tests required use of 15 ppm of carbon, or nearly four times as much as was used in the plant to reach a threshold-odor value of 5. Here again the use of chlorine had no adverse effect on the ability of activated carbon to adsorb odors.

CASE C.

This was a very small plant supplying approximately 0.1 mgd. The raw water was taken from a creek and had a musty or swampy odor with an intensity of 18 threshold-odor units. Water was aerated and then went to a mixing basin, where alum, lime and chlorine, at a dosage of 9 ppm, were applied. After settling, filtration and a post-chlorine application to a residual of 0.9 ppm, the threshold odor was 60, with a chlorinous characteristic.

This particular case is cited primarily because of difficulties encountered in attempting to utilize activated carbon. The operator was apparently not too conversant with methods of carbon application and, furthermore, was handicapped by not having laboratory facilities or proper dry-feed machines. Therefore, once a day carbon would be applied to the mixing basin. This point of application, to begin with, was too close to that of the pre-chlorine application and, secondly, only a small portion of the entire water being handled throughout the day was treated. Recommendations were therefore made that carbon application be made continuously, either to the filter influent or partway through the sedimentation basin.

CASE D.

This was a plant delivering approximately 5 mgd of water, the supply being taken from the Missouri River with an earthy and slightly musty odor, with a threshold-odor value of 30. Primary settling, followed by mixing with alum and lime and subsequent settling, reduced the odor concentration to 22 threshold-odor units, the odor having a musty characteristic. Secondary mixing and settling further reduced the odor to 14 threshold-odor units with a musty characteristic. The water was then chlorinated and given a final settling, with the result that it had an odor concentration of 14 threshold-odor units with a chlorinous, musty characteristic. After this final settling, the water was chlorinated to a free residual of 0.5 ppm and the resultant odor had a concentration of 40 threshold-odor units, with a chlorinous to medicinal characteristic. Laboratory tests on water just after final chlorination, in which ammonium sulfate was applied to a 1:3 ratio with the chlorine, reduced the odor from 40 to 18. The palatability level determined on tap water was found to be 8 threshold-odor units. Carbon dosage on the laboratory scale indicated a dosage of 14 ppm would be required to produce a palatable water. Based on all of the tests that we have conducted in water plants over the past ten years, we have found that considerably larger dosages are required in the laboratory than are necessary in plant practice. In fact, carbon applied within the plant usually gives at least twice as effective results as are obtainable in the laboratory. In case B it will be noted that approximately ¼ of the laboratory dosage accomplished palatability in actual plant tests.

CASE E.

This plant, delivering approximately 8 mgd of water, takes water from a river with an earthy to slightly musty odor and a concentration of 22 threshold-odor units. Raw water was treated with activated carbon and then was delivered to a mixing basin, where coagulants were added, and thence to a clarifier, where partial recarbonation was practiced. Water from the clarifier had a threshold odor of 14, with a potato-bin characteristic. Water was subsequently sent to a mixing basin, where ferric sulfate and chlorine were added. After subsequent settling, water had a chlorinous odor of 22 threshold-odor units. After final carbonation and subsequent filtration, odors remained unchanged in intensity and characteristics. Filtered water was treated with chlorine and also with chlorine dioxide at dosages of 1 to 2.6 lb per mil gal. Tap water had an odor intensity of 28 threshold-odor units. Dechlorination of the filter effluent and also of the tap water showed a sour musty odor of 7 threshold-odor units in each case. Palatability level of this particular water was found to be 6 threshold-odor units. Laboratory tests indicated that 4 lb of carbon per mil gal would be required to produce palatability.

In considering the above specific cases it must be realized that one treatment alone is not necessarily the most economical means of accomplishing palatability. Also it must be realized that some of the various proposed methods are not necessarily compatible, unless the individual points of application are selected with considerable care.

Conclusion

In closing, it would be well to bear in mind that all of the proposed methods for taste and odor control, with the exception of activated carbon, depend primarily upon the ability of the materials to oxidize the odorous substances. Therefore, where such odorous substances are capable of being oxidized to non-odorous or less odorous compounds, these various processes have merit. Activated carbon, on the other hand, accomplishes removal of odors by adsorption, whereby odors in the water are actually removed by concentration on the active surfaces of the carbon. Thus, through adsorption odors are actually removed, rather than changed to some other chemical compound. Based on our experiences in water plants throughout the country, we have come to the conclusion that reported failures of activated carbon in removing objectionable odors have primarily been due to not feeding carbon at the best point of application for effective results and also to a failure to use a sufficient dosage in order to accomplish removal of the odor to the palatable level. We can readily understand and appreciate the desires of plant operators to keep costs of treatment at as economical a level as possible. On the other hand, when tastes and odors occur in high concentrations in a distribution system, the harm created in the minds of the public is far greater than any costs which might be involved on the part of the various chemicals required to produce palatability.

Periods of high odor intensity are usually short-lived and, if the high cost during this brief period of time is averaged out over the year, it will be realized that such costs are not exorbitant.

POWER IN NEW ENGLAND

BY BYRON O. McCOY*

[*Presented January 20, 1949.*]

PUBLIC interest in power has increased greatly in the last 15 years. Some of the factors which are responsible for the present interest in power in New England are:

1. The publicity resulting from the Tennessee Valley Authority program, now largely completed, and the various proposals that similar authorities be established for some of the larger New England river basins, such as the Connecticut and Merrimack.
2. The flood-control program for New England of the Corps of Engineers, U. S. Army, particularly with reference to the related question of whether or not power plants should be installed in connection with these flood-control dams where feasible.
3. The proposed St. Lawrence waterway and power development, which would result in the development of a large increase of hydroelectric power in the State of New York.
4. Atomic power and the research now in progress in the field of atomic power.
5. The rising cost of coal and fuel oil and the labor strife in the coal industry.
6. The drought which occurred in the fall of 1947 and the winter of 1947-48, which focused attention on the power shortages in some areas.

In view of this interest, a special Power Survey Committee was appointed in 1947 by the New England Council to make a thorough study of the power resources of New England. The New England Council is made up of New England business leaders and representatives of the industrial, commercial and agricultural associations of the six states, organized for the purpose of stimulating and co-ordinating co-operative effort for solving regional economic problems, and meeting under the auspices of the six New England governors.

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*Hydraulic Engineer, Chas. T. Main, Inc., 80 Federal St., Boston 10, Mass.

The New England Council's committee, under the chairmanship of E. H. Hunter, Chairman of the New Hampshire Public Service Commission, began its work early in June, 1947, and continued for a little more than a year. The resulting report examines the existing power situation in New England, forecasts the probable growth of power demand over the next decade, indicates the increase in generating capacity which will be necessary to meet the probable demand, and discusses the methods of providing for this increase by new steam, hydro and internal-combustion plants.

The substance of this paper is taken from the Power Survey Committee's report and the figures included herein are taken directly from the report with the permission of the New England Council.

Figure IV-1 shows the growth in the amount of electrical energy generated in New England since 1920.

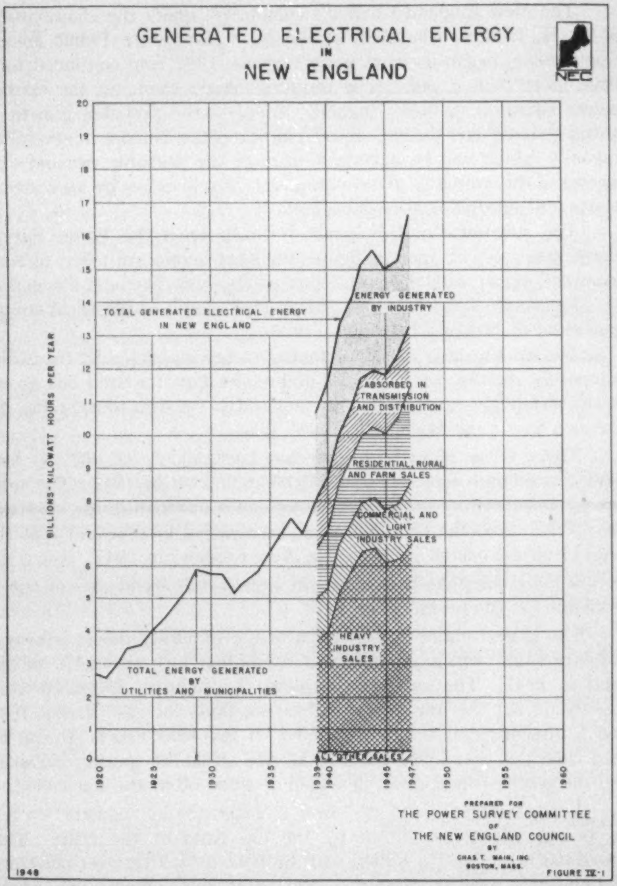
The top line gives the total annual energy generated by the utility companies and by municipalities and shows how the load has grown at an increasing rate, with only temporary setbacks during the depression years and after each World War.

The average annual increase has been about 400,000,000 kwh with a maximum increase of 1,440,000,000 kwh in 1941. The total energy generated by utility companies and municipalities in 1947 was nearly five times the 1920 output and amounted to about 80% of the total electrical energy generated in New England in 1947.

A more complete breakdown of these totals by classes of use is available for the period since 1939.

The largest major classification of use of utility power is heavy-industry sales, which amounted to 6.5 billion kwh or 48.4% of the total in 1947. The purchase of power by industry increased very rapidly during the war years, with a one-third increase during 1941 and a total increase by 1944 of 80% of the 1939 figure. It can be seen from this curve how the load leveled off as the country began to feel the pinch of manpower, and then dropped off as the war ended.

A substantial amount of power is generated by industry for use in its own plants, as shown by the top band of the chart. This amounted to about 3⅓ billion kwh in 1947 or a little over one-third of industry's total requirements, the latter being about 60% of all power generated. There was no net increase in the amount of power



GENERATED ELECTRICAL ENERGY IN NEW ENGLAND

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FIGURE IV-1

generated by industry in the period 1942 to 1947, inclusive, most of the increase in consumption by industry during the war years having been supplied by the utility companies.

The principal gain in utility power consumption since the war has been in domestic and commercial use. Commercial sales, which include stores, office buildings, warehouses, and light-manufacturing shops, amounted to 13.2% of the total in 1947, having increased at a fairly steady rate to about 1¾ billion kwh—an increase of about 40% over the 1939 requirements. Domestic sales, which include residential, rural and farm use, amounted to 21.6% of the total in 1947, having increased at a substantial rate to 2,888,000,000 kwh in 1947—an increase of over 75% since 1939.

It is probably not generally appreciated, but a rather considerable amount of the utility power generated, amounting to about 14%, is absorbed in the transmission and distribution systems.

While this electrical-energy load in kilowatt-hours has been increasing, of necessity, the generating capacity in kilowatts to supply these requirements has also been increasing.

Figure IV-2 shows the growth of generating-plant capacity since 1920.

The lower heavy line gives the capacity of the plants operated by utility companies and municipalities, which increased to a capacity in 1948 about three times as great as the capacity in 1920.

This chart brings out the significant amount of generating capacity built by industry for its own use. However, it is also interesting to note that there has been a substantial decline in this capacity. In 1920, industry owned nearly two-thirds of the generating capacity, while, in 1948, it amounted to only 28% of the total. During the depression years, between 1929 and 1939, numerous industrial power plants were discontinued and industry-owned capacity was reduced from about 1,800,000 kw to 1,200,000 kw. When World War II began, this tendency to reduce industrial capacity stopped, with the result that it has remained practically constant from about 1940 to the present time.

As can be seen from the chart, after a steady growth during the 20's, utility capacity remained constant from 1930 to 1936, with a very gradual increase from 1936 to 1940. During the war years about

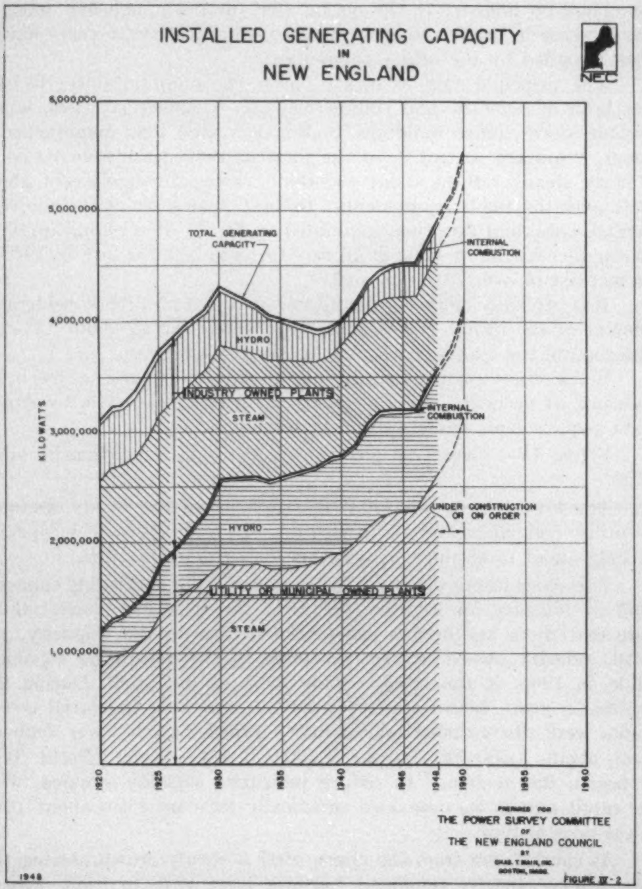

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FIGURE IV - 2

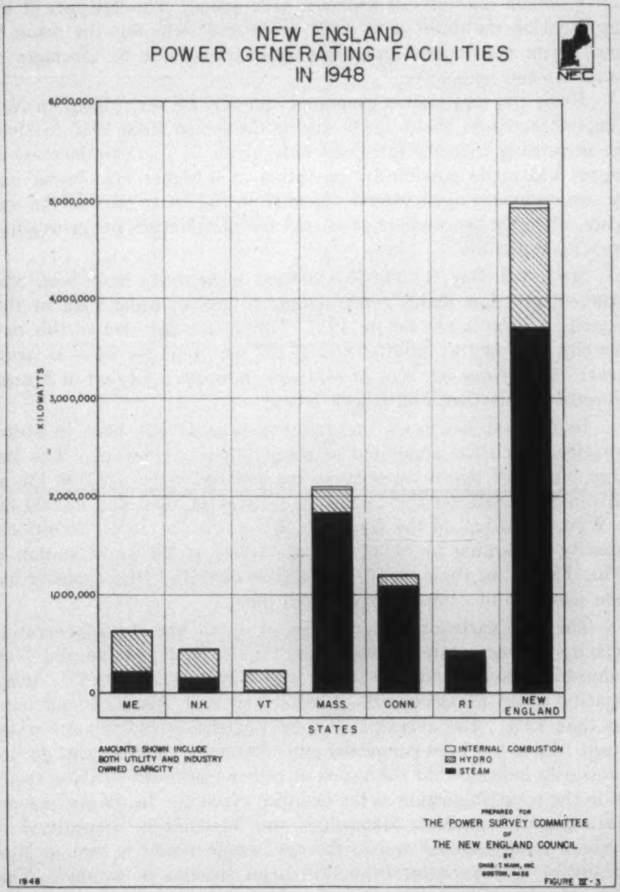
half a million kilowatts of capacity were added. The flat part of the curve during the three years 1944, 1945 and 1946 was the result of government restrictions on power installations, due to shortages of materials and manpower.

While the total power generated annually by the utilities in New England increased about 115% during the period from 1930 to 1946, the generating capacity increased only about 25%. This increase in output was made possible by operation at a higher load factor and by encroachment upon reserve capacity in the latter part of the war years, when the government restricted use of materials for generating-capacity expansion.

Since V-J Day, 1,144,000 kilowatts of capacity have been constructed, are now under construction, or are on order. All of this capacity will be in use before 1951. Ninety-one per cent of this new capacity is owned by utilities and of the new capacity 91% is steam power. Eighty-one per cent of this new capacity is located in Massachusetts, Connecticut and Rhode Island.

In the last ten years the greatest increase has been in steam capacity, which has amounted to about 700,000 kilowatts. The last large blocks of hydro capacity to be installed were 150,000 kw at Fifteen-Mile Falls on the Connecticut River in 1930 and 48,000 kw at Wyman Station on the Kennebec River, also in 1930. Additional capacity amounting to 24,000 kw was added at the latter station in 1940. Except for these plants the total increase in hydro capacity has been made up of comparatively small plants.

The wide variation in proportion of hydro and steam generating capacity between states is shown in Figure IV-3. Maine and New Hampshire have about two-thirds and Vermont has 82.5% hydro capacity while Massachusetts, Connecticut and Rhode Island have less than 12%. The average for New England is 24.7%. All states except Maine are inter-connected and, therefore, these figures do not necessarily indicate that the ratios of power consumed in these states are in the same proportion as the installed capacity. In the wet season, hydro power from New Hampshire and Vermont is transmitted to southern New England and in the dry season power is sent to New Hampshire and Vermont from the steam stations in southern New England over the same transmission lines.



NEW ENGLAND
POWER GENERATING FACILITIES
IN 1948

AMOUNTS SHOWN INCLUDE
BOTH UTILITY AND INDUSTRY
OWNED CAPACITY

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FIGURE IV - 3

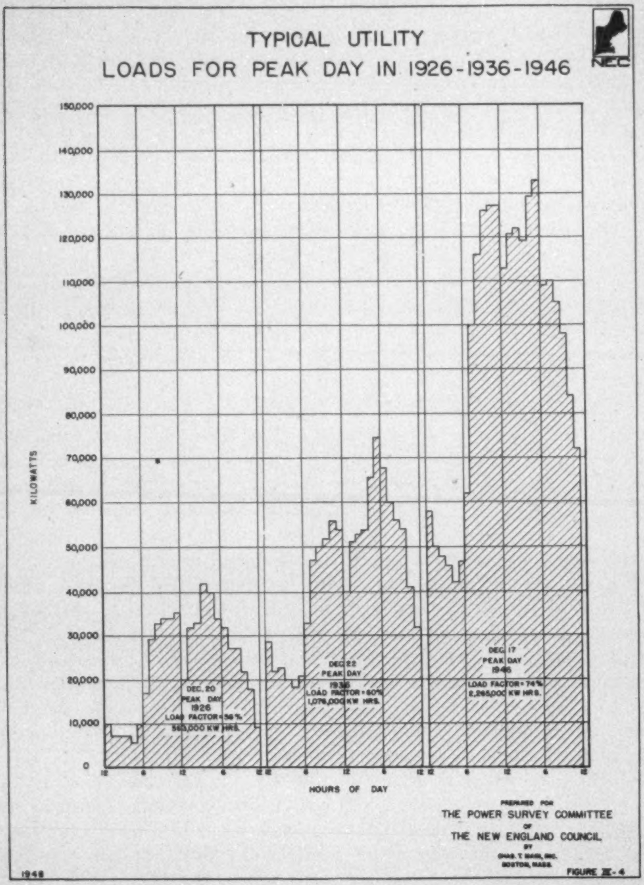
The ability of the utilities to generate 115% more power in 1946 than in 1930 with only a 25% increase in capacity is partly due to increase in load factor. Figure IV-4 shows the change in load factor for a typical utility company on the peak days in 1926, 1936 and 1946. In 1926 the generation required to carry the peak-day load was 563,000 kwh at a load factor of 56%. In 1936 the load had increased to 1,076,000 kwh, but the load factor had increased to 60%. By 1946 the peak-day generation was up to 2,265,000 kwh, or four times the amount generated in 1926. However, with an increase in load factor to 74%, the capacity required to meet the maximum demand in 1946 was only three times the capacity required in 1926.

The peak day for 1943 would probably have shown an even higher load factor. The annual load factors for New England utilities as a whole have increased from 46% in the depression year of 1934 to a high of 59% in the war year of 1943, dropping back to 53% in 1946, and 54% in 1947.

The growth of population in New England and the United States since 1900 is shown in Figure IV-6. The rate of increase in New England since 1940 has been faster than during the preceding ten years. It now averages about 125,000 per year or nearly five times the 27,000 per year for the preceding ten years.

While population increase is of primary importance in estimating power requirements, the rate of increase of per-capita consumption of electricity far outweighs the factor of population increase alone. Figure IV-7 shows the annual per-capita consumption of electricity, based on utility-company sales, for each year since 1926 for both New England and the United States, and it can readily be seen that the consumption of power per capita is increasing rapidly. The average trend between World War I and World War II for New England amounted to an annual increase of 30 kwh per capita. The average annual trend since 1940 amounts to about 60 kwh per capita. The more rapid increase in other parts of the country since 1941 is due to the great expansion during the war of heavy industry, such as the aluminum, steel, airplane and munitions plants, which use large blocks of power and, in general, are not a part of the New England economy.

Upon examination of the growth trends of the three major classes of power consumption, it would appear that domestic power consump-



TYPICAL UTILITY
LOADS FOR PEAK DAY IN 1926-1936-1946

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FIGURE IX - 4

POPULATION
NEW ENGLAND AND UNITED STATES

NEC

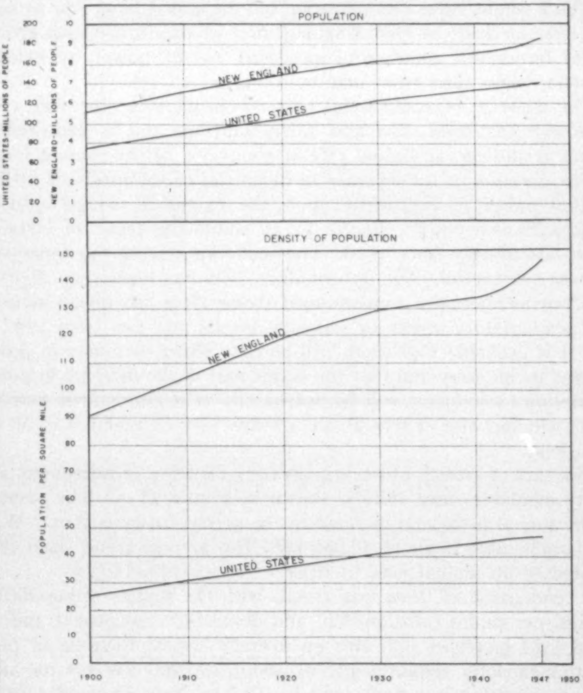

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FIGURE IV-6

tion would account for almost half the future load increase, increasing at an average annual rate of about 10% of the present load. Rural electrification is nearly complete in New England, having expanded from 15% of the farms in 1920 to over 90% in 1947. For the United States as a whole, rural electrification has expanded from 7% to 65% in the same period. In New England most of the future load growth of rural farms will come from increased use of power by existing customers rather than from new customers.

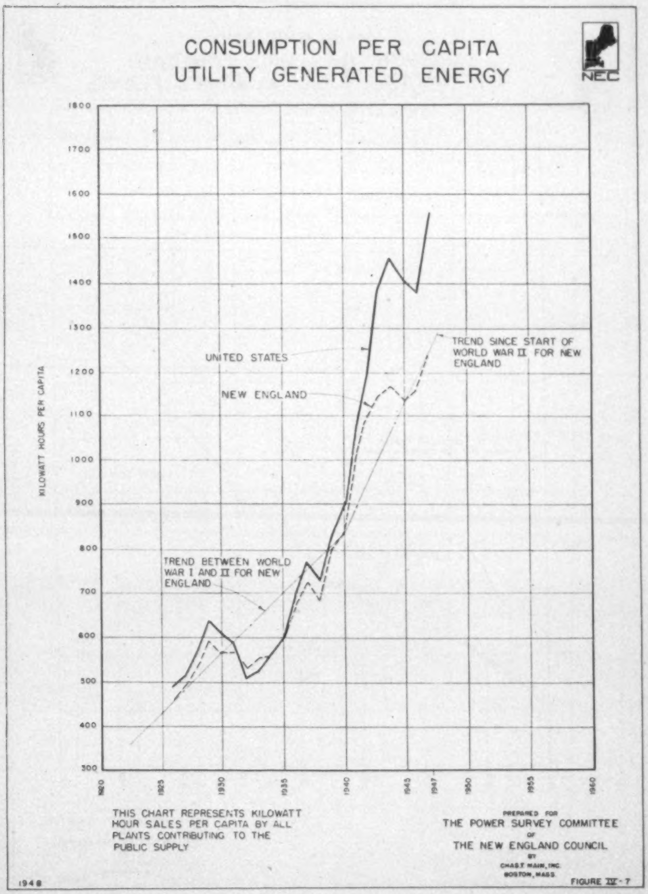
The increase in commercial power consumption since the close of the war has been slow and fairly uniform and is expected to continue at an average annual rate of about 3% of the present load.

The question of the increase in industrial consumption of utility-generated power is dependent upon the extent to which industry generates its own power. Figure IV-10 shows the trend of installed capacity in industry since 1920. The reduction during the depression years was substantial. The upturn since 1939 has been very slight in comparison and actually, as mentioned above, there was no net increase in the generation of power by industry for its own use from 1942 to 1947. It is probable that there will be only slight increases in power generated by industry and that the major part of the increase in power consumption by industry will be purchased. It is anticipated that the amount will increase slowly at an average rate of about 4% of the present load.

The rate of growth of peak generating-capacity requirements and capacity available since 1920 is shown in Figure IV-8. The average trend of annual peak-load increase in the period between World Wars I and II amounted to about 66,000 kw. The average trend since 1940 amounted to an annual load increase of about 125,000 kw.

A comparison of these load trends with the studies of population increases, per-capita consumption, and domestic, commercial and industrial load increases indicates an average annual increase in peak generating-capacity requirements of about 120,000 kw for the next ten years, resulting in a peak load in 1957 on New England's utility systems of 4,000,000 kw.

The upper curve of this chart shows the total installed capacity. This does not represent the capacity available for carrying the load, since allowance must be made for limitations on hydro output, due to lack of rainfall in drought periods. Allowance must also be made



CONSUMPTION PER CAPITA
UTILITY GENERATED ENERGY

THIS CHART REPRESENTS KILOWATT HOUR SALES PER CAPITA BY ALL PLANTS CONTRIBUTING TO THE PUBLIC SUPPLY

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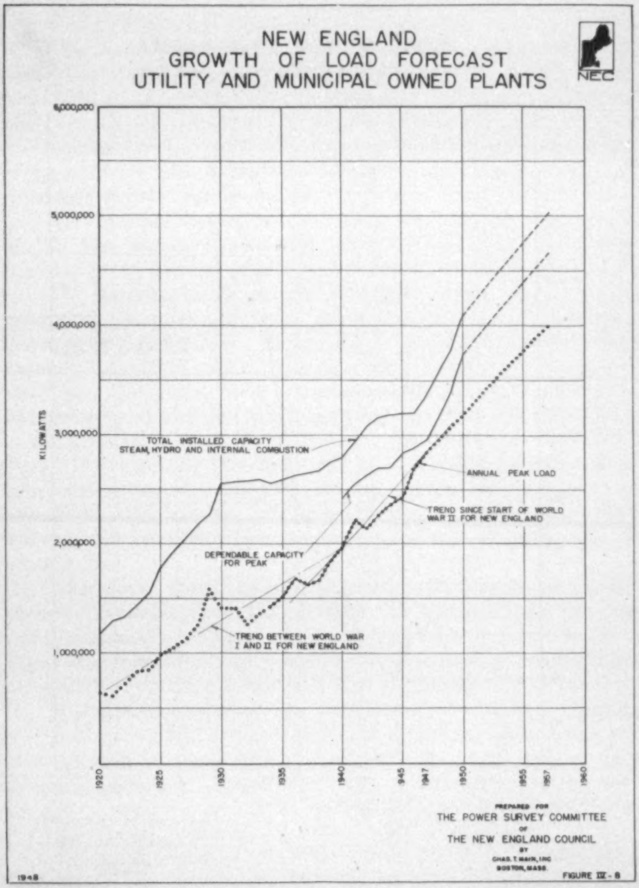
FIGURE IV - 7



NEW ENGLAND
GROWTH OF LOAD FORECAST
UTILITY AND MUNICIPAL OWNED PLANTS

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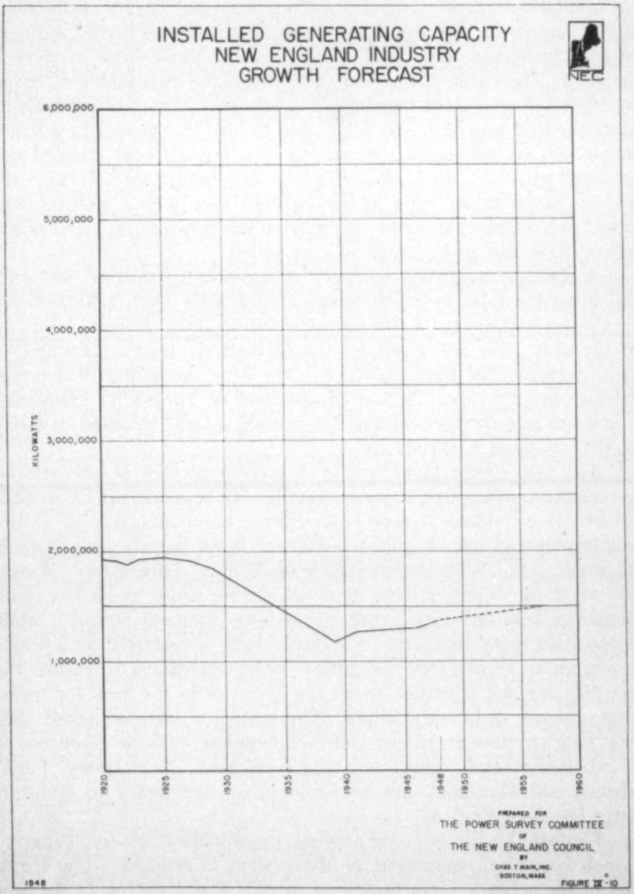
FIGURE III - 8



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NEW ENGLAND INDUSTRY
GROWTH FORECAST

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FIGURE IV-10

for scheduled outages for repairs and maintenance, since with the large steam capacity in New England repairs cannot always be made during off-peak months or in the wet season, because the volume of work is too great. The middle line on the chart shows the dependable capacity. In 1940 the reserve of dependable generating capacity available to carry the load was 22%. By 1947, due to load increases and wartime restrictions on expansions, the reserve was down to the dangerously low level of 4.1%. In Maine, which is not interconnected with the rest of New England, due to the Fernald Law which prohibits the export of hydroelectric power, the reserve was down to zero and power consumption had to be drastically curtailed.

Additional generating capacity under construction or on order will bring the total installed capacity to a little over 4,000,000 kw by 1951. On the basis of the estimated future load growth, as shown on the chart, this will build up the dependable reserve capacity to such an extent that there should be very little possibility of a power shortage by that time. Further installations by the utility companies at a lesser rate should continue, to provide a total installed capacity by 1957 of about 5,000,000 kw.

The map shown in Figure IV-5 gives a picture of the arterial system of New England's power supply. It is made up of a large number of individual systems, extensively interconnected, to assure an adequate and reliable supply of power to all the major centers in the whole area. With the exception of Maine, southeastern Massachusetts in the vicinity of New Bedford and the Cape, and a few small companies here and there, the whole New England system, while representing many independent managements, is operated as a single system under a voluntary committee, which endeavors to insure the best planning and operation of all the facilities in the area for maximum economy and dependability. The system is interconnected with New York's system at Albany and Poughkeepsie, and the resources of the whole northeast region, including New York, New Jersey, Pennsylvania and Maryland, are available in an emergency to transmit power into New England.

Through this transmission network the amount of reserve capacity in each individual component of the system is reduced. The trunk lines of the network serve to deliver surplus hydro energy in the wet months from Vermont and New Hampshire to the industrial centers in southern New England. During low-flow periods steam power from the tidewater steam plants flows back over the lines, to supply the needs of northern New England. At other times when surplus generating capacity is available at the large, modern, efficient tidewater steam plants, power is transmitted to other parts of the system so that smaller, older, less efficient steam plants can be shut down.

Figure VI-1 shows the location of steam and diesel power plants in New England. The symbols are drawn to scale by areas.

As mentioned before, 74% of the generating capacity in New England is steam and about 90% of it is located in the three southern New England states, close to the principal load centers. From 65% to 75% of all electrical energy generated in New England at the present time is from steam plants. For the United States, from 60% to 65% of all energy generated is from steam plants. The exact percentage varies, depending upon the amount of rainfall available for hydro-generated power. This predominance of steam-generated power will be accented in the future, because, except in Maine, the amount of feasible, undeveloped water power is small compared to the expected growth in power demands in the next ten years.

Since V-J Day, 400,000 kilowatts of steam capacity have been installed and by 1951 additional capacity amounting to 630,000 kw, now under construction or on order, will be in operation. During this time only 71,000 kw of hydro will be installed.

With this predominance of steam power, the cost of power in New England, exclusive of Maine, is a function of the cost of steam power.

Steam-power costs are made up of two elements. The first, which is primarily a function of the size of the plant and is known as capacity cost, is made up of fixed charges for interest, property taxes, insurance, and allowance for depreciation, based on the investment cost of the plant, plus operating and maintenance labor, which is primarily a function of the size of the plant. The second, which is primarily a function of the output of the plant and is known as the energy cost, is made up largely of fuel cost.

Fixed charges amount to 12.5%-15% of the investment cost, of which 3.5% to 5% is for insurance and property taxes. Some of the large cities in New England now have a tax rate in excess of $50 per thousand. Cost of money amounts to 5%-6% and depreciation allowances are about 4%. Based on July 1, 1947, cost levels, the investment cost of new steam plants varied from about $150 to $250 per kilowatt. These costs have increased materially since that date. The resulting fixed charges amounted to $18.75 to $30.00 per kilowatt. With $4.00 to $8.00 a kilowatt for operating and maintenance labor, the cost of steam capacity amounts to $22.75 to $38.00 per kilowatt. In Boston, the cost of coal in terms of heat units has risen from 15 cents per million Btu in 1939 to 29 cents in 1947, practically double the pre-war cost. At Hartford, the cost of fuel oil has risen from 17 cents per million Btu to 35 cents, slightly more than double the pre-war cost. As another example, the cost of coal at Montpelier has risen from 28 cents per million Btu to 52 cents in 1947. This latter item illustrates the economy of tidewater steam plants with water-borne fuel delivery. Most of the large steam stations in southern New England are so located. In terms of electrical output these fuel costs range from 3.5 mills per kilowatt-hour at tidewater to 6.2 mills per kilowatt-hour in Vermont.

The location of hydro-electric plants in New England is shown on Figure VIII-1. The symbols are drawn to scale by areas at a slightly larger scale, compared to the preceding chart of steam plants.

Since V-J Day, 71,300 kilowatts of new hydro-electric capacity have either been installed or are under construction, including:

16,800 kw at Union Falls by the Central Maine Power Co.;
15,000 kw at Berlin, a redevelopment by the Public Service Co. of New Hampshire;
5,000 kw at Woods Falls, Vt., by the Public Electric Light Co.;
3,500 kw at Oakdale, Mass., by the Metropolitan District Water Supply Commission;
1,200 kw at Winsor Dam by the Metropolitan District Water Supply Commission;
28,000 kw at Wilder by New England Electric System.

The location of undeveloped water power in New England is shown on Figure VIII-3. By economically feasible is meant a development where the cost of construction and operation is low enough, in comparison to the cost of power from alternative sources, to provide a rate of return on the investment sufficient to warrant undertaking it, with due consideration of the risks involved in the development. Even projects financed with public funds should provide a rate of return sufficient to amortize the investment in a reasonable period of time and justify risking the taxpayers' money.

The remaining, economically feasible, undeveloped power in New England amounts to about 420,000 kw, 263,000 kw of which are in Maine and not available to the other states. The cross-hatched triangles in Figure VIII-3 show dual-purpose, flood-control projects under consideration by the Corps of Engineers, totalling 80,000 kw. If these 80,000 kw and all the feasible undeveloped hydro power in New England, exclusive of Maine, are developed within the next ten years, they would provide only one-quarter of the estimated 1,056,000 kw required to take care of the load growth.

In Maine, there is still more than enough feasible hydro power to carry the estimated 111,000-kw increase in load in the next ten years. The total development of the feasible water power in Maine must wait for a corresponding load growth within the state.

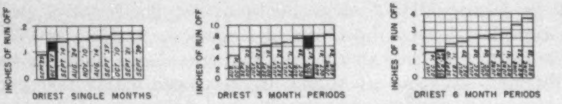
In connection with the various proposals that Valley Authorities similar to the TVA be established for some of the larger New England river basins, such as the Connecticut and Merrimack, the profile of the Connecticut River in Figure VIII-5 shows how extensively it is already developed. Only three economically feasible sites are available. The one at Wilder has already been placed on order.

Figure VIII-8 shows a profile of the Merrimack River with only one economically feasible site remaining.

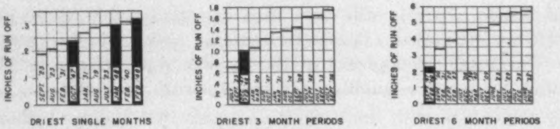
The main river valleys in New England, such as these, are too thickly settled and industrialized to make dual-purpose projects practicable, without destroying values far in excess of possible values added by increased development.

The effect of droughts on dependable capacity of hydro-electric plants was mentioned earlier. The relative severity of the drought in the fall of 1947 and winter of 1947-48 is shown by Figure VIII-2. It shows the ten driest single months, the ten driest 3-month periods, and the ten driest 6-month periods for four unregulated streams used by the United States Geological Survey as index streams, to indicate general, natural stream-flow conditions in various parts of New England. The periods outlined in black are the 1947-48 drought periods. The occurrence of this drought was particularly serious, because of war-time restrictions on power-plant installations, with the

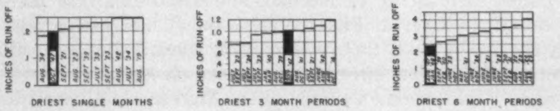
COMPARISON OF LOW WATER PERIODS
NEW ENGLAND INDEX STREAMS



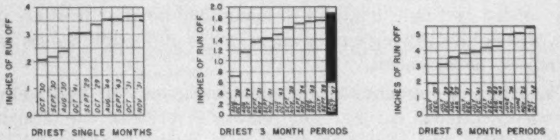
PISCATAQUIS RIVER, DOVER FOXCROFT, MAINE



PEMIGEWASSET RIVER, PLYMOUTH, N.H.



WHITE RIVER, WEST HARTFORD, VERMONT



QUINEBAUG RIVER, JEWETT CITY, CONN.

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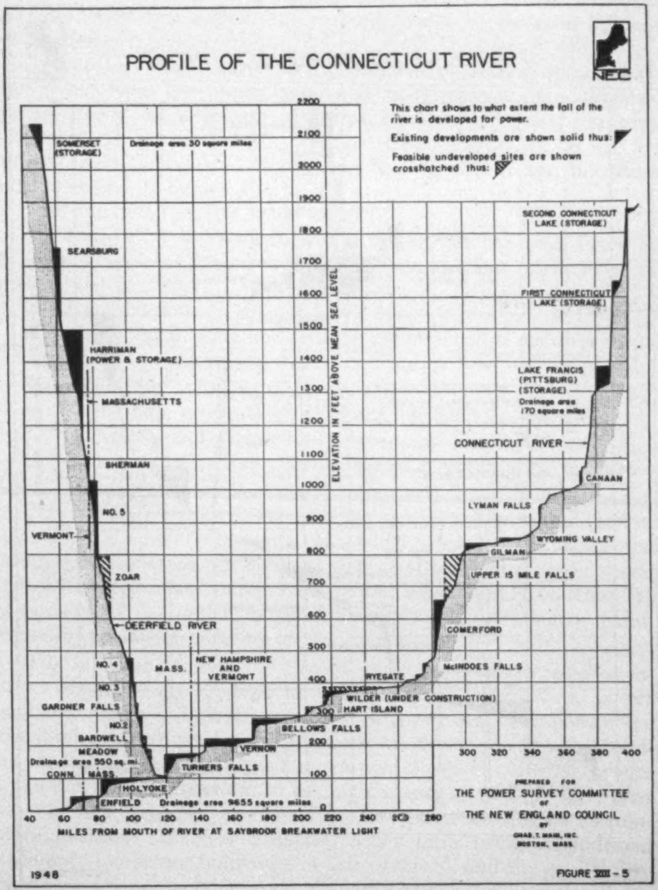
FIGURE VIII-2


PROFILE OF THE CONNECTICUT RIVER
NEC
This chart shows to what extent the fall of the river is developed for power.
Existing developments are shown solid thus:
Feasible undeveloped sites are shown crosshatched thus:
SOMERSET (STORAGE)
Drainage area 30 square miles
SEARSBURG
HARRIMAN (POWER & STORAGE)
MASSACHUSETTS
SHERMAN
NO. 5
VERMONT
ZOAR
DEERFIELD RIVER
NO. 4
NO. 3
GARDNER FALLS
NO. 2
BARDWELL
MEADOW
Drainage area 550 sq. mi.
CONN. MASS.
MASS.
NEW HAMPSHIRE AND VERMONT
HOLYOKE
ENFIELD
Drainage area 9655 square miles
TURNERS FALLS
VERNON
BELLOWS FALLS
HART ISLAND
WILDER (UNDER CONSTRUCTION)
RYEGATE
McINDOES FALLS
COMERFORD
UPPER 15 MILE FALLS
GILMAN
WYOMING VALLEY
LYMAN FALLS
CANAAN
CONNECTICUT RIVER
LAKE FRANCIS (PITTSBURG) (STORAGE)
Drainage area 170 square miles
FIRST CONNECTICUT LAKE (STORAGE)
SECOND CONNECTICUT LAKE (STORAGE)
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
40 60 80 100 120 140 160 180 200 220 240 260 280
300 320 340 360 380 400
MILES FROM MOUTH OF RIVER AT SAYBROOK BREAKWATER LIGHT
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OF
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BY
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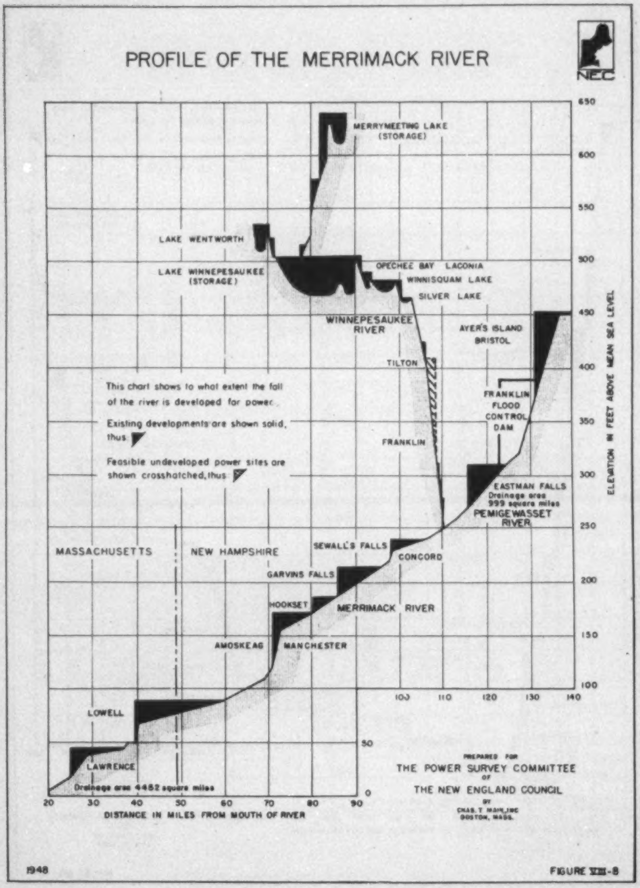
FIGURE XIII - 5



PROFILE OF THE MERRIMACK RIVER

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FIGURE VIII-8

consequent encroachments upon capacity reserves as the post-war loads increased faster than the reserves could be replaced by new construction.

The cost of power varies in any locality, depending on the character of the load, the transmission and distribution system, the size, type and age of the generating facilities, local tax rates, and operating efficiencies. It consists of six principal costs, which can be divided into two main parts, fixed charges on the investment and operating costs, as shown in Figure V-1.

The fixed charges are made up of:

1. Return on investment, which varies, but has been taken at 6% for purposes of this chart and amounts to about one-quarter of the total cost of power.
2. Depreciation.
3. Taxes, local, state and federal, accounting for about one-fifth of the total cost of power.

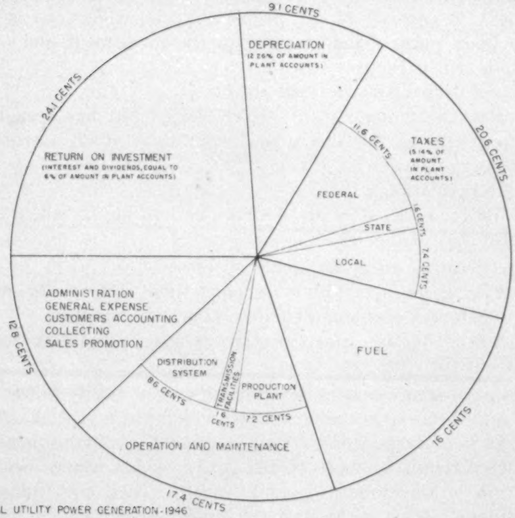
The operating costs are made up of:

1. Fuel costs, accounting for about one-sixth of the cost.
2. Operation and maintenance labor and supplies.
3. Administrative and general expense, accounting for about one-eighth of the cost.

This particular chart is the *average* cost of utility power in New England and is based on the year 1946, which was a year of substantial rainfall. In an average rainfall year somewhat less hydro power would be produced, requiring more steam power, which would increase the fuel portion of the dollar to about twenty cents, with minor modifications in the other portions of the chart.

It is fallacious to cite the cost of power as a major cause of industry's leaving New England to locate in areas where cheap power is available. In most industries the cost of power is a small percentage of the total cost of manufacturing in comparison to wages and material costs. Only in a few cases, such as certain chemical industries where the amount of power consumed per unit of production is large, does the availability of cheap power have any important bearing on its competitive position. In New England, paper mills using groundwood are the only important industries in this category, and the availability of cheap power and suitable wood has largely fixed their location.

DIVISION OF COST DOLLAR OF NEW ENGLAND CLASS A & B UTILITIES 1946



TOTAL UTILITY POWER GENERATION-1946

CLASS A&B UTILITIES EQUALS ABOUT 97% OF THESE FIGURES

STEAM PLANTS	8,597,000,000 KW HR
HYDROELECTRIC PLANTS	3,667,000,000 KW HR
INTERNAL COMBUSTION PLANTS	44,000,000 KW HR
	12,308,000,000 KW HR

1946 WAS A GOOD HYDRO YEAR - AN AVERAGE YEAR WOULD PRODUCE SOMEWHAT LESS HYDRO AND MORE STEAM POWER WITH MINOR CORRESPONDING ADJUSTMENTS IN THE CHART

NOTE

CLASS A & B UTILITIES ARE PRIVATELY OWNED UTILITIES HAVING ANNUAL REVENUES OF $250,000 OR MORE AND INCLUDES ABOUT 97% OF THE UTILITY GENERATED POWER

ALL DATA FOR THIS CHART WAS OBTAINED FROM FEDERAL POWER COMMISSION SOURCES EXCEPT THE FIGURE FOR RETURN ON INVESTMENT WHICH WAS ASSUMED TO BE 6%

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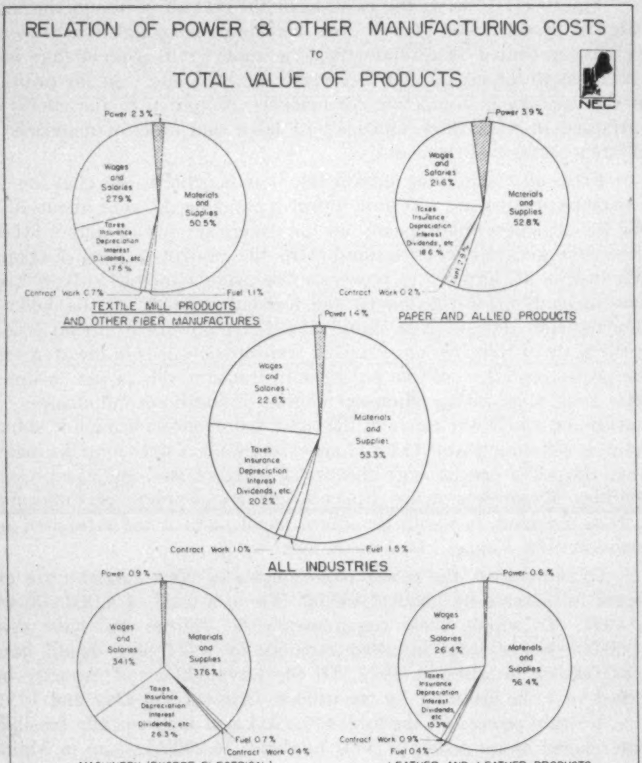
FIGURE V-1

Figure III-1 shows the relation of the cost of power to the total value of products for four of New England's principal industries, as well as for United States industry as a whole. It is evident that wide variations in the cost of power would have little effect on the position of the industry in competing for markets, compared to the effects of variations in wage rates, efficiency of labor and costs of materials in different sections of the country.

From an engineering standpoint, it is feasible to develop the St. Lawrence project and transmit within reasonable distance about 700,000 kw of dependable capacity on the American side. Figure VIII-13 shows the geographical relationship of the project to New England. Whether or not any of this power can be made available to New England depends on the action by the legislative bodies of the Federal Government, State of New York, and Canada. There already exists in the State of New York a system of transmission lines in the area near the project, which could be enlarged to transmit this power to upper New York State with a minimum amount of additions and changes. A market for this power exists in this area and, from an economic standpoint, it is impracticable to build new transmission lines long distances, when the power can be more cheaply disposed of close by over present facilities. Regardless of this, if a certain block of power were allocated to New England, it would be only a small part of the estimated increase in New England load in the next ten years.

To summarize, the power requirements of New England are expected to increase by about 1,167,000 kw to a total of 4,000,000 kw in 1957. To supply these requirements the utilities will have over 4,000,000 kw of total installed capacity by 1951 and should have 5,000,000 kw installed by 1957. Of the 1,144,000 kw of capacity installed, or to be installed, by the utilities between V-J Day and 1951, 91% is steam power. Of the total 420,000 kw of economically feasible, undeveloped hydro power in New England, 263,000 kw are in Maine and will more than cover the expected increase in demand in Maine for the next ten years. The remainder represents a small part of the expected increase in demand in the next ten years in the rest of New England. Except in Maine, the economics of New England's power supply will continue to be related directly to the cost of steam power.

Because water power was a prime factor in the original develop-



RELATION OF POWER & OTHER MANUFACTURING COSTS TO TOTAL VALUE OF PRODUCTS

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FIGURE III-1

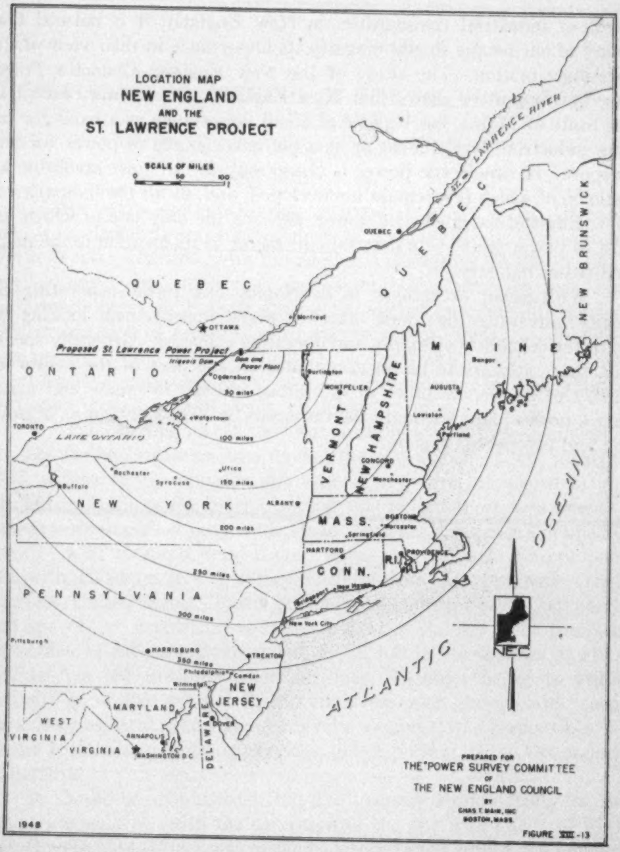
LOCATION MAP
NEW ENGLAND
AND THE
ST. LAWRENCE PROJECT
SCALE OF MILES
0
50
100
ST. LAWRENCE RIVER
QUEBEC
NEW BRUNSWICK
QUEBEC
Montreal
OTTAWA
Proposed St. Lawrence Power Project
Dam and Power Plant
Iroquois Dam
ONTARIO
Ogdensburg
50 miles
Watertown
100 miles
TORONTO
LAKE ONTARIO
Rochester
Syracuse
Utica
150 miles
Buffalo
NEW YORK
ALBANY
200 miles
250 miles
PENNSYLVANIA
300 miles
Pittsburgh
HARRISBURG
350 miles
TRENTON
Philadelphia
Camden
Wilmington
NEW JERSEY
MARYLAND
WEST VIRGINIA
VIRGINIA
ANNAPOLIS
WASHINGTON D.C.
DELAWARE
DOVER
New York City
Burlington
MONTPELIER
VERMONT
NEW HAMPSHIRE
CONCORD
Manchester
MAINE
Bangor
AUGUSTA
Lewiston
Portland
MASS.
BOSTON
Worcester
Springfield
HARTFORD
CONN.
New Haven
Bridgeport
R.I.
PROVIDENCE
ATLANTIC
OCEAN
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FIGURE XIII-13

ment of industrial communities in New England, it is natural that many of our people should magnify its importance in their view of the existing situation. The study of the New England Council's Power Survey Committee shows that New England water power, except in the State of Maine, has become of small importance as a basis for future industrial development or as a potential source of power for any purpose. Hydroelectric power is cheap only in the most favorable locations, of which few remain undeveloped, and, of all the industries of New England using electric power, perhaps the only one to which the cost of power might be a determinant factor in its location is the pulp-and-paper industry.

With minor exceptions, in developing new power-generating capacity, advantage has been taken of every improvement looking toward the reliability of supply and operating economy. Generally speaking, there appears to be an acceptance on the part of the utility industry of its responsibility in the public interest to create and maintain a power plant adequate for the needs of New England as a growing and prosperous region.

SANITARY ENGINEERING IN THE OCCUPIED ZONE OF GERMANY

BY ALVIN F. MEYER*

[*Read January 20, 1949.*]

MANY years ago a book was written, entitled "Wade, In Sanitary" (1), depicting some experiences of Sanitary Corps personnel in World War I. The title, with the emphasis changed—"Wade In, Sanitary"—depicts the situation of the Sanitary Engineers on duty with the armed forces in Europe during the recent post-hostility period. The combination of a variety of problems, plus a shortage of qualified sanitary engineers, in the Medical Department and a similar shortage of professional engineers in the Corps of Engineers placed an unusual load upon those few individuals available for duty.

A brief explanation of the organization of sanitary engineering services in the European area during the period July, 1946, to Sept., 1948, will serve to emphasize the type of activities performed by the Air Force Sanitary Engineer. During this period there was one (1) Sanitary Engineer on duty with Headquarters, European Command; one (1) with Headquarters, United States Air Force in Europe; one (1) with Headquarters, Military Government; one (1) with Headquarters, United States Constabulary; one (1) with Berlin Command; and one (1) at Bremerhaven Port—a total of six (6). The Engineer with Office of Military Government, U. S., left in the summer of 1947, leaving five (5) full-time offiers on duty. In order better to utilize the service of this personnel, the engineers with the ground troops were assigned areas, and the Air Force engineer was responsible for all Air Installations sanitary services, plus a portion of the Ground Installations.

It should be emphasized that the primary responsibility of the sanitary engineers (with the exception of the one with Office of Military Government, U. S.) was to render professional advice and conduct inspections in connection with U. S. Military activities only. The Sanitary Officer assigned to the Office of the Military Government, U. S., was responsible for assistance and advice to the German public health personnel. In actuality, this was not quite the case, as will be seen later.

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* Major, MSC (USAF), Acting Chief, Preventive Medical Section, Office of the Surgeon, Hq. AMC, Wright Patterson Field, Dayton, O.

The spring and summer of 1946 saw the changeover of the armies in Europe from those of combat troops awaiting rotation to a stabilized occupational force. In the case of the ground troops, movement from temporary camps to permanent ones was in progress and there was a multitude of sanitary problems incident to this. The Air Force units were occupying, in most cases, former Luftwaffe air bases and, in many instances, destruction of these bases by allied bombing had been extensive. Simultaneously with the changing of the character of the occupation forces came the arrival of dependents of the occupation troops. This produced new problems in the field of environmental health.

The problem of water supply was a continuous one. It has lasted throughout the occupation. Two major conditions required action: first, the question of quality from a bacteriological standpoint was a primary concern; secondly, even under optimum conditions European standards for water quality are considerably lower than those of the United States. Many of the supplies were not adequately protected from a sanitary standpoint. Allied bombing had resulted in numerous breaks in mains and adjacent sewers. This same bombing had also, in many cases, destroyed or badly damaged water works. The influx of refugees and displaced persons produced serious overloading of facilities.

In order to cope with this problem, orders were issued forbidding United States personnel from using water from other than approved sources, and requiring the use of individual or unit sterilization methods (such as the Lister Bag, boiling, etc.) when such approved water was unavailable.

In order to approve municipal or military-installation water supplies, a comprehensive program of sanitary surveys and bacteriological testing was inaugurated. A wide variety of water supplies had to be considered. Water systems were of all kinds and sizes, and in all conditions of repair. With the exception of those units installed by the initial occupying troops, chlorination facilities were almost completely absent. Obviously, before approval could be given for use of a municipal or base water system, the sanitary survey had to be very complete and a thorough assessment of the possibilities of contamination had to be made. Sizes and types of chlorinators had to be determined, and information furnished the Corps of Engineers regarding their installation.

During the course of approximately one year, complete data on the municipalities and air bases classed as United States Air Force in Europe exempt air installations were collected. These data included: maps of each supply; data as to size and length of mains; type of source (if wells, the depth, casing, drawdown, year installed, etc.); amount of reservoir storage; pumps (make, model, type, capacity); and general data regarding the condition of the system; possible sources of contamination; and information regarding chlorinators installed, on order, or required. Considerable time had to be spent interviewing German water-works personnel and translating the data into United States terms. The cubic meter soon replaced the gallon in the engineers' thinking and pipe sizes began to be thought of in millimeters rather than inches. All of these data were consolidated and posted on a large chart. Estimates of additions required were also prepared.

Standards for approval and continual sampling were patterned after those recommended by the United States Public Health Service. It should be remembered that the responsibility for furnishing water to the armed forces is that of the engineers (in the Air Force, the Air Installations Division). The Medical Department is responsible for determining the quality and advising the engineers with reference to standards for construction and operation. For approval, a minimum of 0.4 ppm chlorine residual was required throughout the active parts of the distribution system, as evidenced by daily tests for a period of fourteen (14) consecutive days. In addition, not less than fourteen (14) consecutive daily series of potable bacteriological samples were required. For continuation of approval, the daily chlorine tests had to indicate the presence of the 0.4-ppm residual. Bacteriological samples were collected on a routine basis, the frequency depending on the population served by the system. The population was calculated on the basis of United States Military plus the indigenous inhabitants. For populations up to 2500, one sample per month was required; 2500—24,999, eight per month, and for 25,000 up, daily samples were necessary. Approved supplies were listed in an official directive, published periodically to show changes. Failure to maintain proper chlorine residuals resulted in removal of supplies from the approved list. Similarly, if less than 20 samples per month were collected, one non-potable sample would remove the supply from the approved status. Two non-potable samples in any one month would remove the supplies submitting over twenty (20) samples. In order to secure reapproval, the basic requirements for approval for chlorination had to be satisfied, and reëvaluation of the bacteriological quality made on the basis of either fourteen (14) daily potable samples or other numbers, as indicated by knowledge of the system.

Of almost as great importance as the problem of insuring adequate bacteriological safety of the water was the situation with regard to quantity. As pointed out above, many of the municipalities had experienced influxes of refugees and their water systems were grossly overloaded. The Luftwaffe had planned the water supplies for the majority of their bases on the normal European requirements for domestic consumption, which is apparently far below the demand of United States personnel. Even with the extra volume required for fire protection, the presence of United States troops and dependents, with an average per-capita demand of around 100-150 gal per day, overtaxed the existing facilities. In many communities reservoir storage had been depleted by the fire demands of the air raids. Further complicating the situation was the fact that the German has an inherent dislike for the use of surface water and almost without fail prefers ground water. Hence, when in the summers of 1946 and 1947 a severe drought occurred and the ground-water table was depressed, the water shortage became a serious and major problem.

It would be possible to go into considerable discussion of many of the problems at the various installations serviced by the United States Air Force of Europe Sanitary Engineer. However, a discussion of one major problem will serve to point out the many sanitary engineering problems in this field which were attacked.

The municipality of Wiesbaden is located some 28 miles from Frankfort and is situated on the Rhine River, just below the point of confluence of the Rhine and Main. With a normal population of approximately 200,000, there were in the spring and summer of 1946 approximately 250,000 indigenous plus approximately 10,000 United States personnel. Water for the city was derived from two distinct sets of sources. The major portion of the water was procured from a series of horizontal galleries in the Taunus Mountains surrounding the city. From these galleries the water flows by gravity to distribution reservoirs and thence into the three zones of the city (high, middle and low). The daily production of water from the galleries was about 6 mgd. In former years, prior to the war, the galleries had also been filled with a reserve storage of approximately 500 mil gal. This reserve was completely lost during the bombing raid on Wiesbaden, which produced some 240 major breaks in the distribution system. A second source of water was a novel system of filter galleries along the Rhine River at Schierstein. A similar system is described by Steel in "Water Supply and Sewerage" (2). Rhine River water was pumped into four (4) large settling basins scooped into the sandy soil along the river shore. This water percolated into the substrata and was picked up by pumps in a well field approximately 100 yd away. As the sand was heavily contaminated with iron and manganese (which the raw river water was not), a slow sand filter plant was located at Schierstein. The capacity of this installation was roughly 3 mgd. Water was pumped by steam reciprocating pumps to reservoirs in each of the three zones. Although careful studies were made in conjunction with the German authorities, even as late as the summer of 1948 additional information regarding location of various units of this system was being uncovered. There were fourteen (14) major galleries, an undetermined number of shallow wells, five (5) major distribution reservoirs, and a complicated tangle of valve and piping layouts. To complicate matters further, a line leading to several smaller towns nearby was discovered, and the Air Field on the edge of the city was also found to be serviced from this system.

The initial occupation troops had installed chlorinators at the Schierstein pump works and at each of the then known distribution reservoirs. These units were 40-lb-per-day, manual-control gas machines. Satisfactory residuals were being maintained through the major portion of the community, as far as could be ascertained, and a limited approval had been issued to the supply.

As the summer progressed, the water shortage became more acute. It was common to hear individuals debating the merits of certain carbonated beverages for tooth-brushing purposes, and equally common to hear others report that these same beverages were not suitable for bathing purposes. As the problem affected both indigenous and military alike, the United States Air Force of Europe Sanitary Engineer, the Air Installations Officer, the Military Government Sanitary Engineer, the Utilities Division of Military Government and the local Wasserwerk Director met in frequent consultation. A thorough joint study was made of the capability of the Wiesbaden water system to supply the demands placed on it. About this time a rash of complaints was received that the Germans were "shutting off the water" in certain areas. It was obvious that this was not the case, but that there was just not enough water to fill the mains. The survey revealed that, on the basis of 50 gal per capita daily, there was an overall shortage of approximately 6 mgd. Numerous plans for increasing the supply were discussed. Among these were proposals to expand the filter plant and basins at Schierstein. This had to be abandoned, due to the non-availability of the necessary well pumps. Another proposal was the drilling of deep wells, but the lack of adequate geological data plus the previously mentioned shortage of well pumps ruled that proposal out. A proposal that the Germans build a modern rapid sand filter plant met with considerable opposition. This was not unexpected. One of the desirable features, from the local water people's viewpoint, of the river filter system was the maintenance of even temperatures. This factor is one rarely considered in this country. Conversations with Mr. Waring of the Ohio State Board of Health recently indicated that he had received similar information from the Stockholm water superintendent with regard to an installation there. A second point in opposition was the use of chemicals for coagulation and sedimentation, and thirdly and most important, the Rhine water is so highly contaminated that there is a definite mental block to its use.

Little was accomplished on this problem during the summer and fall. It was apparent that positive steps would have to be initiated before the next year. Late in the winter the Military Government personnel located an industrial rapid sand filter plant in a seized war industry at Biebrich on the Rhine near Wiesbaden. About four (4) miles of water main would be required to connect this plant to the municipal system. A survey was made of the plant and recommendations were furnished the Germans. Although the United States personnel advocated the use of alum and soda ash as coagulants, the director of the water works wished to use ferric chloride in conjunction with chlorine, and this was finally adopted. The industrial plant required considerable modification for municipal use, including the erection of a pumping station, improvement to the river intake, erection of dosing tanks, and six coagulation basins, etc. To one not accustomed to the German way of doing things, or to one not familiar with the difficulties incident to attempting to build anything requiring steel and concrete in the post-war German economy, the delays, troubles and problems produced might seem comic or ridiculous, but in fact they were far from it. The German insistence upon use of some rather complicated fixtures, such as special porcelain filter inlets for combination air and water wash, slowed down construction considerably, due to the delays in delivery. By summer of 1947 it was apparent that the shortage of water was going to be more acute than during the previous year and also that the plant would not be completed until late summer. Several unexpected problems contributed to the retarding of work. One of the major items was the inability of the Germans to locate high-lift pumps, required to move the approximately 3 mgd from the plant up into the city. Practically the entire pump-production capacity in the United States and British zones was destroyed. Efforts to obtain pumps from plants which had been seized for reparations to Allied Nations met with little success. Eventually the required pumps were found.

Meanwhile, the lot of the United States Air Force of Europe Sanitary Engineer was not a happy one. Wiesbaden happens to be the location of the Air Force Headquarters and some of the areas affected by the water shortage were those occupied by dependent families. Likewise the previously mentioned hotels were in the center of the shortage area. The complaints were long, loud, and many in number. Even the indigenous population took its pen in hand and dispatched letters to the Surgeon's Office. One comes to mind, penned in typical German handwriting, complaining of the lack of water to flush the commode and blaming the occupation authorities for taking all the water. After listening to a day of this, the said Sanitary Engineer wended his way homeward to assist his wife in carrying several pailfuls of water upstairs, in order to have a bath, and several more to wash dishes!

At last, in early August the plant was completed and placed in operation. Instead of the anticipated 3-mgd production, initially only 1.5 mgd were obtained. This was blandly blamed on sun-spots interfering with the level of the Rhine, but was traced to excessive depth of filter sand, with resultant short filter runs.

A brief description of this installation might be in order. The chemical plant which had formerly used the filters was situated on the bank of the Rhine, just opposite its confluence with the Main River. Water was taken from the Main, under the Rhine, and then into the plant. The city built a complete new building, containing the high-lift pumps to the city, the coagulation and sedimentation basins, chlorinators, and office and laboratory facilities. Water came into the plant at the first level and was dosed with ferric chloride and about 2 ppm chlorine, with agitation in two upward-flow mixing tanks, from which it flowed into two pairs of two-unit sedimentation towers, similar in appearance to Dorr Clarifiers, only deeper and smaller in diameter. Flow through these towers was downward under a circular weir, upward and out at the upper level over a sawtooth circular weir. From here the water was piped out of the dosing plant to the filters. There were six (6) filters, with an estimated capacity at 2½ gal. per sq. ft. per min. of 3 mgd. Effluent from the filters was discharged into a clear-well and thence pumped to the city. Chlorination was accomplished in the clear-well. By the late fall of 1947 the plant was producing approximately 2½ mgd.

The use of ferric chloride resulted in a heavy incrustation of the filter sand with iron. This condition was not alleviated, although by late summer of 1948 the flumes leading to the weirs had a heavy incrustration of iron also. Due to shortages of metal, no rate controllers were installed until spring of 1948. Also, no loss-of-head gauges had been located and, although recommendations were given for a simple one of the mercury-manometer type, this equipment was not improvised.

During the winter of 1947-48, the galleries in the mountains were cut off for the major portion of the period and allowed to begin refilling. The water demand from the indigenous population fell off with the advent of cool weather and the two filter plants were able to satisfy most of the demand. This accumulated storage, plus the additional water from the new station, allowed the city to enjoy a summer free of water-shortage difficulties in 1948.

One last point with regard to the plant should be noted. Discussions with the Municipal Waters Works authorities after completion of the plant revealed that they planned on using the unit as a pilot plant for further studies. These further studies indicated that the final plan for the new Wiesbaden water plant involved the use of ferric-chloride coagulants, sedimentation, and then pumping the effluent back into the sandy soil along the river, and extending the existing well field.

Although problems in the water-supply field were numerous, it should be remembered that many other phases of sanitary engineering offered problems to be solved. Sewage-disposal plants were needed at several new air bases being built, and design studies were made for the Air Engineer. Quite a discussion could be presented regarding one of these, but time does not permit.

The rehabilitation of barracks and the necessity for conserving fuel required that studies on space and heating be made. These studies were coördinated with engineer and other Medical Department personnel of higher Headquarters, so as to maintain uniform standards.

Last but not least, some mention should be made of the aerial dispersal of insecticides conducted in the European and North African area. Initially, this program revolved around one small L-5-type aircraft, equipped with a 50-gal. tank. This plane was equipped at the request of the Berlin Command and used to disperse DDT along the Teltow Canal in Berlin. Rubble, blown bridges and unexploded munitions made ground spray activities almost impossible. The Armed Forces' stand on aerial spraying of insecticides is that such procedures are a useful adjunct to normal, ground control measures, and not a substitute therefor. As there were several areas in which ground measures were not complete, the equipping of two C-47-type aircraft was authorized during the winter of 1946. These planes were modified in accordance with plans revised by the Sanitary Engineer and were placed in use the following summer. In addition to missions in Berlin and elsewhere in the occupied zone, almost worldwide attention was focused on them when they were dispatched to Egypt, to assist in controlling the cholera epidemic there in the early part of 1948. Less well-known was their use in assisting the Austrian Government in the control of larvae of the nun-moth, which were destroying several of the state forests in Styria.

In summary, the practice of sanitary engineering with an overseas Air Force Command during the post-hostilities period offered a variety of opportunities to consider nearly every phase of the profession. In addition to the standard approaches to problems, the individual's outlook had to be adapted to meet the needs of crossing a language barrier in many cases and to the dictates of necessity. Excellent opportunities for exercise of good engineering judgment were presented. From a public health viewpoint, the fact that the engineer also, in most cases, was playing a large role as a preventive medical specialist with regard to environmental sanitation made the experience a valuable one.

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THE NEW YEAR'S FLOOD OF 1949 IN WESTERN MASSACHUSETTS

BY ANGELO IANTOSCA*

[*Read February 17, 1949.*]

THE meteorological circumstances preceding the so-called "New Year's Eve Flood of 1948" consisted of a low-pressure area centered over northeastern Kansas, which was moving eastward fairly rapidly, causing general precipitation from Kansas to New England. Simultaneously a low-pressure area over North Carolina had developed and was moving northward. On December 30, the two disturbances merged and moved northeastward. A low-pressure area over the Hudson Bay region and a comparatively narrow trough over western New England and eastern New York carried the warm moisture-laden air from the south into contact with the cold air in the north, with the result that extremely heavy precipitation occurred. The period of rainfall extended from about 8:00 a.m. on December 29 to sometime in the evening of December 31, 1948, when the rain turned to snow and ended during the morning of January 1, 1949.

Due to the lack of snow cover and the frozen nature of the ground, optimum conditions for rapid runoff prevailed. Furthermore, the entire area affected is generally hilly and precipitous, where even under ordinary conditions runoff is fairly rapid. Rivers reacted quickly and rose to flood stage early in the morning of December 31. Most of the flood peaks were reached during the afternoon of December 31. The peak on the Housatonic River near Great Barrington was not realized until the morning of January 1, a condition which may be attributable to the time lag, direction and center of concentration of the storm. Recession of the rivers was rather slow at the outset, due to large valley storage and natural restrictions in the waterways.

Figure 1 shows graphically the total rainfall and water equivalent of melted snow involved in the flood under discussion in the area shown during the 3-day period, December 29, 30 and 31, 1948.

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*Junior Sanitary Engineer, Massachusetts Department of Public Health, 511A State House, Boston 33, Mass.

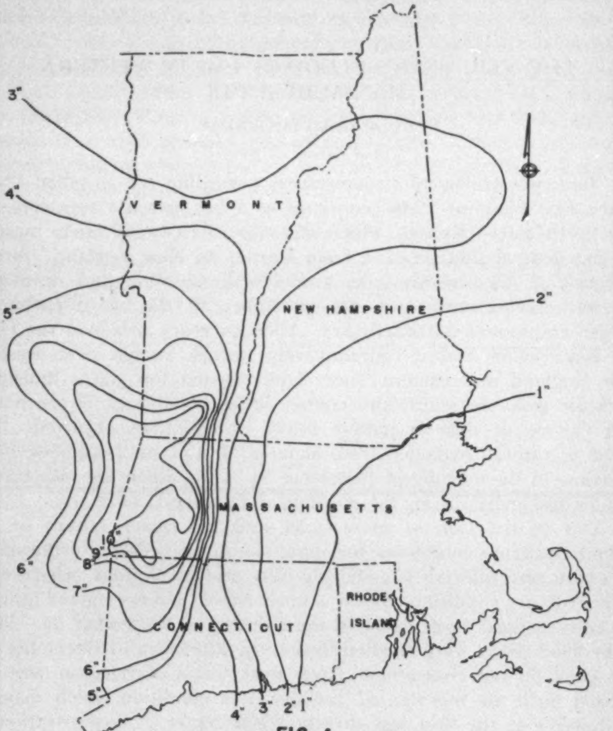
3"
4"
VERMONT
5"
NEW HAMPSHIRE
2"
1"
MASSACHUSETTS
10"
9"
8"
6"
7"
RHODE ISLAND
CONNECTICUT
6"
5"
4"
3"
2"
1"

FIG. 1
ISOHYETAL LINES
STORM OF DECEMBER 29, 30, 31, 1948

For purposes of comparison, peak stream flows in the rivers indicated for the flood of September, 1938, and the one recently experienced are shown in the following table:

	Peak flows — cfs	
	Sept., 1938	Dec., 1948
Hoosick River		
At Adams	5,080	4,500
At Adams (No. Branch)	8,450	6,100
At Williamstown	——	13,000
Deerfield River		
At Charlemont	56,300	46,400
Westfield River		
At Goss Heights	19,900	8,830
At Huntington	21,800	11,900
Housatonic River		
At Coltsville	6,400	5,520
Near Great Barrington	11,520	12,800
Farmington River		
At New Boston	18,500	11,700

The general area of Massachusetts affected by the storm may be designated as lying west of the Connecticut River and including the basins of the Hoosick, Housatonic, Deerfield, Westfield and Farmington Rivers, the basins of the Hoosick and Housatonic Rivers receiving the brunt of the blow. The drainage areas affected are shown in Figure 2.

In the Westfield, Deerfield and Connecticut River basins no serious damage to water-works or other facilities occurred. The Knightville Reservoir on the East Branch of the Westfield River, completed in 1941, filled and discharged moderately over the spillway for the first time. The spill was claimed to have occurred well after the peaks on the river had passed, so that damage on the lower Westfield and Connecticut River basins was minimized considerably. The flood on the main Connecticut River was only moderately high, having been exceeded by the floods of recent years.

General flooding of dwellings and business establishments in the low-lying areas occurred, with resulting damage to property and destruction of foodstuffs and other commodities. Water supplies and sewerage systems in addition to roads and bridges were affected. Due to the adverse public-health conditions attendant upon disasters of this type, a standard emergency plan of the Department of Public Health

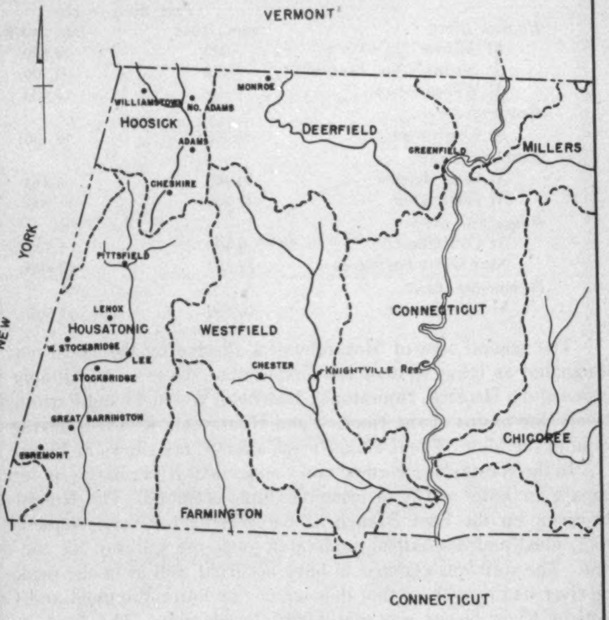
VERMONT
MONROE
WILLIAMSTOWN
NO. ADAMS
HOOSICK
ADAMS
DEERFIELD
GREENFIELD
MILLERS
CHESHIRE
NEW YORK
PITTSFIELD
CONNECTICUT
LENOX
HOUSATONIC
WESTFIELD
W. STOCKBRIDGE
LEE
CHESTER
KNIGHTVILLE RES.
STOCKBRIDGE
GREAT BARRINGTON
CHICOPEE
EGREMONT
FARMINGTON
CONNECTICUT

FIG. 2
RIVER DRAINAGE AREAS

was set in motion at the first indication of possible flood conditions on December 30, 1948. This plan consisted in the establishment of an "around-the-clock" operations center at Amherst, which would act as a clearing-house and reception center for field activities and in the dispatch of personnel, supplies and instructions to critical points, as well as in advising the Department in Boston as to needs and conditions as the situation developed.

The regular personnel of the two departmental districts involved was immediately augmented by five engineers and one supervising sanitarian from the Department's main office in Boston. Upon arrival at Amherst, this personnel was briefed as to the conditions in so far as possible and immediately dispatched to the area affected, with several portable emergency chlorinators and a trailer-mounted chlorinator, capable of supplying dosages to water supplies of more than 300 lb of chlorine daily, in addition to a supply of hypochlorite compounds, so as to be prepared to cope with any public water-supply emergency and to assist local water and sewer departments. On the morning of January 1 several sanitary officers and food and drug inspectors of the Department were sent into the flood zone, prepared to offer assistance and advise local Boards of Health primarily in connection with problems of milk and food sanitation and the disinfection and treatment of places and facilities affected by flood waters.

When it became obvious on the morning of December 31 that serious public-health conditions were being created, radio and telephone instructions were issued, recommending that all water in the affected area used for drinking and culinary purposes be rendered safe by the boiling procedure. Literature on proper procedures for disinfection was issued as soon as practicable and also circularized by publication in local newspapers.

Due to the precipitous nature of watersheds and excessive amounts of runoff, the energy-laden waters carried much debris and caused considerable damage by undermining and erosion. In the Hoosick River valley the water supplies of three communities were affected.

In North Adams, three river crossings, where pipe-lines lay in the bed of streams, were undermined and disjointed. The intake works of one source of supply were clogged by debris and therefore became inoperative. Washout of a small portion of the distribution system on one street occurred. Fortunately, the three chlorinators on the water system were not adversely affected, so that it was possible to step up dosages to a degree where residuals would carry for a considerable distance into the distribution system. A boiling order was placed in effect by the Board of Health until conditions surrounding the supply and favorable bacteriological examinations of water samples indicated that the water was safe for consumption without further treatment.

In Adams, which is served by a surface- as well as a ground-water supply, the former was shut down and the ground supply used alone, due to fear of washout and the danger of pollution. No serious damage resulted, outside of a fluctuation in pressure, caused evidently by one washed-out river crossing, which was brought under control by the closure of valves. A boiling order on this supply was in effect during the period of the flood.

In the Housatonic River valley, in the town of Lee, which derives its water supply from two sources, each of which is provided with hypochlorinators, the damage was considerable. The intake dam on the Washington Mountain supply was washed out and the pipe-line blocked by debris in the form of boulders and earth, carried along by a raging torrent which, during normal periods, is a gentle mountain brook. As a result, this supply was put out of operation. A pipe-line across the brook, leading from the reservoir, was washed out. The pipe-lines across the Housatonic in East Lee and at Lenoxdale were also destroyed. The entire supply for the town was therefore taken from Codding Brook, whose watershed is adjacent to the Washington Mountain supply and which was not disrupted by the heavy runoff. A boiling order was in effect during the emergency period.

Two river crossings at Great Barrington were also destroyed. The supply for the town is partially derived by means of an infiltration gallery on the Green River. This gallery became flooded and it was necessary to install a temporary emergency chlorinator in the pumping station.

In the towns of Chester and Cummington, pipe-line crossings of relatively small diameter were also dislodged and removed from service. Several of the reservoirs on small supplies were filled or partially filled in with debris in the form of earth, sand and rocks. The water of practically all of the surface supplies in the area became turbid, a condition which indicated the establishment of boiling orders, due to the fact that the turbidity was noted in the distribution systems. Also, under such conditions the probability of the rapid dissemination of pollution throughout distribution systems is enhanced. The limited value of sedimentation in the storage basins of these supplies was also eliminated, due to the turbulent conditions which prevailed.

The principal duties of the engineers of the Department were to ascertain conditions of water supplies and to be prepared to be of service with emergency chlorinators and to assist in reëstablishing normal water service as much as possible. Frequent consultations and field inspections with water-department officials were the order of the day, in order that an up-to-the-minute picture of the developing situation might be available. All permanent chlorinators were examined and dosages increased where possible, in order to provide higher residuals.

In connection with the chlorination of water supplies during emergency periods, it should be standard operating procedure that every effort be made to increase chlorine dosages from normal amounts to ones which will carry throughout the distribution system. The reason for this belief is that, besides furnishing protection at the source, an additional safety factor will be provided in the distribution system, in anticipation of breaks and attendant back-siphonage and other pollution which may be introduced. Secondly, the elimination of any prior pollution which has been introduced will be more quickly effected, so that boiling restrictions which have been imposed may be removed with a minimum loss of time. There can be no doubt that boiling orders maintained over protracted periods of time are highly ineffective, due to complacency on the part of the public.

In order to determine the sanitary quality of the water, frequent samples of water for bacteriological examination were taken. In order to expedite this work, the services of the laboratory of Pittsfield Health Department and the Tri-Town Health Department laboratory in Lee were utilized. Fortunately the majority of the water supplies showed favorable bacterial results within a short period of time, so that it was unnecessary to maintain these laboratory facilities for any extended period, in so far as the State Department of Public Health was concerned.

As a result of the destruction of river crossings, several temporary crossings in the form of hose-lines and temporary pipe-lines were installed. In the larger communities it was possible to maintain the supply of water on opposite sides of rivers, due to the nature of the distribution system. No large areas were left without water in the communities affected, due primarily to the quick and efficient action of the local water departments, which operated with dispatch and efficiency under adverse conditions.

At the present time all water departments have reëstablished the water mains across waterways. In two of the communities, these mains have been removed from the river and installed on bridges, in order to prevent a recurrence of the disruption of service by floods of the magnitude experienced.

Besides affecting the water supplies, the disaster also affected the sewerage and sewage disposal of the communities in the flood areas. General flooding and surcharging of sewers and storm drains occurred, resulting in damage by silting, undermining and clogging. In some cases, the head-walls of sewers discharging to the river were undermined and will therefore require some reconstruction. In those communities where sewage-disposal works were placed out of operation, only slight damage to the actual treatment works was noted upon recession of the flood waters. Two sewage-disposal plants which were affected were those at North Adams and at Pittsfield. The North Adams plant was placed out of operation, when the flood waters reached the stage where it was no longer possible to discharge to the river. During the shutdown period, an obstruction occurred in a large intercepting sewer on River Street, which prevented sewage from entering the plant for a short period after the flood waters had receded. This intercepting sewer was cleared and repaired after some difficulty, and sewage is now flowing through its normal channels. In the Pittsfield sewage-treatment system a large pipe-line, which leads from the pumping station at the sedimentation basins, which were flooded, to the secondary treatment works, was washed out. This pipe was replaced within a short period of time by a temporary line.

In connection with the sewage-treatment works in the Connecticut Valley, the plants at Greenfield and Springfield were put out of operation for a period of approximately three days. It is of interest to note that during the 1948 spring thaw these plants were also out of operation for the same period of time. No damage was caused to the Springfield plant, as it was adequately protected by the high dike which surrounds it. The plant at Greenfield required the removal of electrical equipment. However, other units were partially inundated, but did not appear to be adversely affected and only necessitated a good-housekeeping operation prior to the resumption of normal activities.

Several observations were noted which it is felt should be worthy of mention, even though the factors involved appear to be fundamental in water-works practice. The first is the maintenance of records and ties on the location of valves and other appurtenances on the distribution system. Water-supply control units, such as chlorinators and valves, should be so located that during times of emergency they will be readily accessible and the effect of damage thus minimized.

Much has been learned during this flood and from previous experiences of a similar nature that should be of value in future alterations, extensions or improvements in connection with water supplies. Although costs may not permit or conditions warrant the establishment of water systems and other facilities to withstand major floods, the lessons learned should be taken into consideration. Such procedure, in the final analysis, is good engineering practice.

By January 6 most of the adverse conditions in the flooded areas had cleared sufficiently so that the additional men, sent out by the Department to augment the regular personnel, were withdrawn and returned to their regular stations. The boiling orders placed on water supplies for the emergency were repealed. This was particularly important, inasmuch as the reopening of schools in several instances was being held up on this account.

The damage caused by the flood was claimed by the Berkshire County Engineer, in a statement to the press on January 12, 1949, to have been close to $3,000,000—the most destructive storm in this county's history. The two cities of Pittsfield and North Adams and all of the 30 towns are included in this estimate, which does not include the considerable loss incurred by private property. The damage to water works, sewerage and sewage-disposal works is estimated at approximately $250,000. It is recognized that the figures above quoted are subject to revision in either direction, due to inability accurately to estimate and survey the total damages, in order to obtain actual cost figures for restoring facilities to normal.

Before closing, the author wishes to acknowledge the assistance of members of his organization, who supplied information used in this paper and who worked so diligently and effectively in the flood areas. It is also desired to recognize publicly the quick, efficient action of local water-department personnel, who worked unceasingly during the emergency to maintain normal water service and who, as was expressed to the author in visits following the emergency, sincerely appreciated the advice and help given by the State Department of Public Health.

EFFECTS OF MUNICIPAL WATER TREATMENT ON BOILER-WATER CONDITIONING

BY J. N. WELSH*

[Read February 17, 1949.]

IN THE conditioning of both municipal and industrial water, there is the same general objective of imparting to the water those characteristics that represent optimum service for the intended uses. Both use the same raw material, the water from lakes, rivers and wells. Both are confronted by the same natural impurities, such as color, suspended matter and hardness. Both have to contend with further impurities —different from those supplied by nature—arising from careless disposition of the waste from increasing density of population and growing industry. Corrective measures for this condition, while making headway, are still far from fruition. But municipal water, on the one hand, is a mass-production job of producing in all cases a safely potable, palatable, clear water, with more or less attention given to holding iron and manganese content low, and restricting hardness to some extent. On the other hand, industrial water treatment must meet the widely diverse demands of our technical way of life, whether in the utility or in the industrial plant, the restaurant, laundry, dairy or home. With uses so widely different and each needing special characteristics in the water it employs, it is evident that the problem of treatment in every instance must encompass the unique features that will provide those special characteristics.

USES OF WATER

The uses of water can be shown diagrammatically, as in Figure 1. Preliminary general processing is frequently accomplished individually by industrial plants. However, this division of the diagram can be considered as applying to the treatment given at the municipal plant to produce the safely potable, palatable, clear water previously mentioned, whether this treatment be merely clarification and chlorination or one of the more involved processes, embodying softening by lime-soda or base exchange.

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* Director of Engineering Service, Hall Laboratories, Inc., Pittsburgh, Pa.

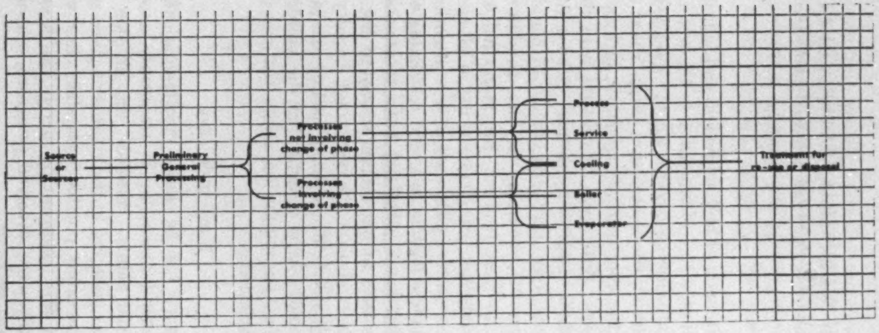
Source or Sources
Preliminary General Processing
Processes not involving change of phase
Processes involving change of phase
Process
Service
Cooling
Boiler
Evaporator
Treatment for re-use or disposal

FIG. 1.—PATH OF WATER FROM SOURCE TO ULTIMATE DISPOSAL.

As the water from the municipal plant reaches the consumers, its use will be divided between two processes: those not involving change of phase, and those involving change of phase in which there is evaporation of water. The water is already in satisfactory condition for many uses in the first category, since it is suitable for drinking and service water. Nevertheless, there are numerous plant processes requiring further treatment, such as softening or demineralization. Successful use in a once-through cooling system may require additional chlorination for control of microörganisms, stabilization for prevention of calcium-carbonate deposition, or treatment for control of corrosion in piping and heat exchangers. Even in the home special treatment is necessary in mechanical dishwashers. In general, however, the problems met are relatively simple.

In the second category, where change of phase is involved, the problems are more difficult. This division of the diagram relates to the use of water in recirculating-cooling systems and for generation of steam, at all temperatures and pressures up to critical—705° F. and 3,206 psig—superheating of steam extending the temperature range to 1,000-1,100° F. Concentration in the recirculating-cooling systems poses problems of microörganism control with bactericides and algaecides, softening and/or stabilization with glassy phosphate, frequently supplemented with acid treatment for prevention of deposit formation, and application of chemicals such as chromate or glassy phosphate for control of corrosion. In the process of continuous generation of steam concentration is far more critical. Water of varying purity is introduced into the generator, and as pure steam as possible is withdrawn, leaving behind the boiler water or brine, containing all but the volatile impurities. Blowdown of boiler water or brine from the generator limits concentrations. In a salt-water evaporator on shipboard, operating at sub-atmospheric pressure, the brine may represent 1.5 concentrations of ocean water or a concentration of approximately 50,000 ppm. In a typical steam boiler, generating 850,000 lb of steam per hour at 1,400 psig and driving an 85,000-kw turbogenerator 24 hours a day for months on end without interruption, feedwater is all condensate and evaporated makeup, and concentration of dissolved solids in the boiler water amounts to 200 ppm or less, with blowdown merely a trickle. In between the low-pressure evaporators and high-pressure steam generators using distilled water as feed, there are the myriad boilers operating at high and low pressures and high and low steam temperatures, generating a few hundred to 1,000,000 lb of steam per hour and using varying percentages of raw or treated water as makeup in the feedwater. All, including the low-pressure evaporators and high-pressure generators receiving all condensate as feedwater, require attention to treatment and conditioning of the water, if troubles with deposit formation, corrosion, carry-over and embrittlement are to be avoided (1).

Comments on the last division of the diagram will be limited to the statement that treatment of waste water for re-use or disposal is of paramount importance from the standpoints of economy and of avoiding pollution of surface-water supplies.

Treatment of Municipal Water in Relation to Its Use in Boilers

With the broad picture of municipal water uses already painted, use for purposes other than steam generation will be omitted from further discussion. Also, it is not the purpose of this paper to discuss in detail all of the intricacies of treating the water before it enters the boilers, or within the boilers. Rather, it is the intention to consider, in a more or less general way, some of the treating procedures you employ in the municipal plants, and to estimate the effects, if any, in the steam-generating plants.

Chlorination

Aside from no treatment whatever, which is certainly rare at the present stage of our development, simple chlorination is the minimum treatment you employ in the municipal water-treating plants. Normally the few tenths ppm of residual chlorine maintained in the water leaving the water works is dissipated before the water reaches the steam-generating plants, so this presents no problem. A possible benefit of simple chlorination is the oxidization of some organic matter in the water which might be harmful in the boilers.

Break-point or super-chlorination is something else. Beneficial effects can be greater than with simple chlorination. For instance, certain types of organic coloring matter naturally present in surface waters decompose in the hot, alkaline boiler water to form compounds which cause foaming and carry-over (2). If there is localized evaporation practically to dryness in boilers, decomposition of organic matter at these locations can produce relatively insoluble organic compounds, which contribute to formation of deleterious deposits. Also, organic matter with dispersive properties will seriously interfere with hardness removal in hot-process softeners. Although the usual method of removing organic coloring matter from water is coagulation and filtration, destruction of a substantial part of the organic by super-chlorination can be decidedly helpful.

Water polluted with sewage or certain types of industrial waste can contain substantial amounts of ammonia, as well as albuminoid nitrogen which is potential ammonia in the steam from boilers. All ammonia contained in the water introduced to boilers will be driven off in the steam and, if the concentration in the steam is greater than about 1 ppm, serious and costly damage can ensue at points where there is condensation of steam in contact with copper or copper-bearing alloys (3). Even with less than 1 ppm of ammonia in the steam, a large steel plant in the Pittsburgh district experienced serious loss of copper-bearing alloy tubes in an air-ejector condenser, because of accumulation of ammonia to a concentration of more than 80 ppm in the gases being vented. In an Ohio steel plant using Cuyahoga River water in the boilers, samples of condensed steam have been found to contain as much as 26 ppm ammonia. Here again, break-point or super-chlorination can have a beneficial effect in the steam-generating plants, since the process will destroy all, or practically all, of the ammonia in the water.

Chlorination can be harmful in at least one respect, if the residual-chlorine concentration is not low and closely controlled. The carbonaceous and resinous base-exchange materials used for pretreatment of boiler feedwater are sensitive to chlorine, because of its powerful oxidizing property (4). Thus, unless the chlorine concentration of the water to be treated is less than approximately 0.5 ppm, dechlorination with a chemical such as sodium sulfite is necessary, to prevent intolerable loss of exchange material.

One other aspect of chlorination is the use of ammonia in conjunction with chlorine to form chloramines. Such contamination with ammonia, if of significant magnitude, can be a source of worry to the operating personnel in steam power plants where the boiler feed is condensate and evaporated makeup, and where a determined effort is made to keep ammonia concentration of the steam at a minimum, for protection of condenser and closed-heater tubes. One such case is that of a large Southern utility plant, where institution of chloramine treatment of city water, which was used in the evaporators, introduced enough ammonia to the evaporated makeup water to produce a concentration of approximately 1 ppm in the steam from the boilers. Whether a concentration of this order is dangerously high is controversial, especially if dissolved-oxygen removal at the deaerating heater is so effective that the remanent concentration in the feedwater is no more than a slight trace. Nevertheless, higher ammonia concentrations could eventuate in the after condensers, endangering tubes in this equipment, and the operating men wished to reduce ammonia in the system without going to great expense to pretreat the evaporator makeup for removal. Significant reduction was accomplished by discarding drips from the after condensers, even though this meant wasting normally good condensate.

Coagulation and Filtration

Filtration, or coagulation and filtration, is one of the most common procedures you employ in the treatment of municipal water. The process of coagulation utilizes chemicals such as iron sulfate (ferrous or ferric) or aluminum sulfate, alkali chemicals such as lime or soda ash and, in increasing instances, coagulation aids such as activated silica or clays of special types. Removal of suspended and much organic matter from the water is accomplished, and dissolved-solids concentration is not materially increased, unless heavy burdens of suspended or organic materials require heavy dosages of coagulating chemicals. By such clarification the municipal water plants do a real service to the consumers using the water for steam generation, since otherwise many of these consumers would of necessity do the job themselves.

The deleterious effects of certain types of organic matter in boiler feedwater have already been mentioned in the discussion of chlorination. What can eventuate if these effects are ignored is well illustrated by the experience of a large paper-manufacturing plant in South Carolina. When the plant was constructed, approximately 10 years ago, the engineering department was given due warning that the soft, highly colored river water available should be freed of the contaminating organic matter before being used in the new boilers, which would generate 120,000 lb of steam per hour each, at 425 psig and 650°F. Because of the desire to hold expenditures for equipment at a minimum, the warning was not heeded and operation was started with no provision for pretreatment. Intolerable conditions developed immediately. Foaming and carry-over were so severe that superheaters and turbines became fouled with deposits and thus operation of the whole plant was endangered. Continued operation was rendered possible by frequent cleaning of superheaters and turbines, until eventually suitable equipment for clarification was installed.

Silt is a normal contaminant of surface waters, particularly during periods of heavy run-off, and its presence in ground waters is not uncommon. If the pretreating equipment in the steam-generating plant is of the base-exchange type, the silt and other suspended material must be removed before passage of the water through the equipment; else loss of capacity will ensue due to fouling of the exchange material. If the water is used raw in the boilers, failure to remove silt will increase suspended solids, silica and aluminum concentrations of the boiler water. Removal of reasonable amounts of suspended matter is compatible with simultaneous reduction of hardness in cold-process, lime-soda pretreating equipment, since the temperature of the water is low enough to obviate significant dissolution of silica and aluminum from the suspended matter, even though alkalinity is relatively high. In hot-process equipment, however, conditions of temperature and alkalinity are such that dissolution of considerable silica and aluminum from silt can seriously interfere with the maintenance of optimum conditions in the boiler water.

Why is it essential to avoid introduction of aluminum and uncontrolled amounts of silica to boiler water? It is not the purpose of this discussion to delve deeply into the technical aspects of these factors. Suffice it to say that under certain conditions aluminum in boiler water can result in the formation of sodium-aluminum-silicate scale (5) at the evaporative surfaces, and to avoid problems of silica, complex-silicate, or magnesium-phosphate deposit formation in the boilers, or silica deposition on turbine blades, boiler-water silica concentration must be controlled at varying levels, depending upon factors such as operating pressure, ratings, boiler design, slagging of furnaces, uses of steam, and relative concentrations of other boiler-water constituents.

Apropos of the difficulties that can be encountered through failure to remove suspended matter from boiler feedwater is the experience of a chemical plant in Baltimore, Md. (6). For ten years this plant waged a discouraging and unsuccessful battle against the formation of sodium-aluminum-silicate scale in the 600-psig, 120,000-lb-per-hour boilers. The fundamental cause of the trouble was recognized to be clay in the well water used and efforts were directed toward improving the quality of the boiler feedwater by repairing well strainers, abandoning the use of water from some wells and making up the deficiency in water with city water, recovering more condensate, and changing chemical conditions in the boiler water. Such efforts were futile and finally, when steam consumption required the installation of an additional boiler, decision was made to include suitable pretreating equipment, the most important part of which was equipment for preliminary coagulation and filtration. Subsequent operation for the past two years has proved the wisdom of this move, since there has been no further development of complex-silicate scale.

Anent the subject of coagulation and filtration there is one further minor point that should be mentioned. The activated-silica sol used as a coagulant aid is sometimes prepared with ammonium sulfate as the activating reagent. Addition of coagulation aid, prepared in this manner, to municipal water supplies obviously contributes to the ammonia concentration of steam generated from the water. Fortunately, because of the small amounts of coagulant aid normally used, ammonia added to the steam from this source should be small in amount.

Softening

In many areas where the water available is very hard, your municipal plants are equipped to soften water with lime, with lime and soda ash, or by base exchange. The net effects are good from the standpoint of the consumer who is using the water for steam generation.

On the whole, you as municipal plant-operating men are not interested in reducing hardness much below 100 ppm calcium carbonate. Even so, hardness reduction to this extent is a boon to the steam-generating plants, because many small, low-pressure plants can use the water economically without further pretreatment, employing chemical conditioning of the boiler water with satisfactory results and at reasonable cost. Even large, high-pressure plants, which must do additional pretreating, will spend less for chemicals to treat the municipal water than the very hard, natural water, and possibly will find the capital expenditure for the necessary pretreating equipment to be appreciably lower.

Of less concern to you is the effect of softening on potential carbon-dioxide concentration of steam generated from the treated water. Carbon dioxide in steam dissolves, at least in part, in the water produced by condensation. This reduces the pH value of the condensate and leads to corrosion of heat exchangers and piping which are contacted by the condensate. Without reviewing the theories of corrosion or contemporary procedures for reducing carbon-dioxide concentration of steam, suffice it to say that the concentration should be as low as possible (7).

Sources of carbon dioxide in steam are dissolved carbon dioxide, bicarbonates and carbonates in the boiler feedwater, and sodium carbonate, which is frequently fed to boilers to produce the desired alkalinity in the boiler water. Dissolved carbon dioxide, if not removed from the boiler feedwater in an open or deaerating-type heater, will be driven out of the boiler water into the steam. At the temperature of the boiler water, bicarbonate will decompose completely to form carbonate, with liberation of carbon dioxide, and then hydrolysis of carbonate present as sodium carbonate will produce hydroxide in the water, with liberation of additional carbon dioxide in the steam. It should be pointed out here that, if no phosphate is used in the boiler water of low-pressure boilers, carbon-dioxide concentration of the steam will be minimized by precipitation of much of the carbonate as calcium carbonate. On the other hand, phosphate conditioning (8), which is essential for prevention of scale formation at pressures in excess of about 150 psig, will result in precipitation of calcium phosphate, and the sodium carbonate produced by the reaction will be free to hydrolyze and liberate its carbon-dioxide content.

Thus, in lime-treating waters high in temporary hardness for reduction of hardness, municipal plants automatically render another service to the consumers using the water for steam generation without further pretreatment. Removal of free carbon dioxide and substantial reduction of bicarbonate concentration with the lime result in lowering the potential carbon-dioxide concentration of the steam produced by the boilers. In addition, the use of an expensive chemical like cyclohexylamine (9), which is employed to reduce corrosion in return lines by neutralizing the carbon dioxide and raising the pH value of the condensate, might be rendered economical, whereas consumption would be too great with the natural water being fed to the boilers.

From the standpoint of hardness, sodium base-exchange softening has the same beneficial effects in steam plants as lime or lime-soda softening. However, base-exchange treatment does not affect the concentrations of free carbon dioxide and bicarbonate in the water and thus, from the standpoint of the steam-generating plant, it is inferior in this respect to lime or lime-soda treatment, where the water is high in temporary hardness. Since base-exchange treatment in the sodium cycle does not affect bicarbonate concentration of the water, high temporary-hardness waters so treated contain sodium-bicarbonate alkalinity which, if appreciable in amount, will produce high alkalinity in the boiler water, unless heavy blowdown is given the boilers. Choice of pretreating equipment, in steam plants requiring it, is also affected by partial base-exchange softening, since the equipment best suited to removal of sodium bicarbonate from the water can be entirely different from the equipment best suited for removal of temporary hardness. However, no general conclusions can be drawn and choice of type of equipment must be based upon individual plant requirements (10).

Stabilization and Corrosion Control

You usually accomplish stabilization of lime- or lime-soda-treated municipal waters by recarbonation or by use of glassy phosphate (11). The former procedure augments carbon-dioxide concentration of steam produced from the water and the effect of this has already been considered in the discussion of softening. On the other hand, it minimizes the formation of calcium-carbonate and/or magnesium-silicate deposits in boiler-feedwater heaters, since the lower the pH value of the water, the less danger there is of precipitation of these compounds, when water temperature is increased to more than 200°F. The latter procedure, which involves the addition of 1 or 2 ppm of glassy phosphate to the water at the municipal water-treating plant, has little effect as far as the generation of steam is concerned. Of course, phosphate consumption is slightly reduced in the plants using phosphate for conditioning of the boiler water. The only detrimental effect is interference with proper softening in plants pretreating boiler feedwater in cold-process, lime-soda softeners, but this difficulty can be overcome by using a coagulant in the softeners to adsorb the glassy phosphate.

Glassy phosphate is used by municipal water-treating plants for corrosion control (12) as well as for stabilization, but previous remarks on effects in boiler plants need not be supplemented. Another procedure for controlling "red water" is to increase the pH value of the water by feeding an alkaline chemical, such as lime or soda ash. The addition of lime raises the hardness of the water and thus increases chemical consumption in the boiler plants. Soda ash does not have the same effect on hardness, but it does increase the amount of carbon dioxide in the water that can be released in the steam. Normally the increase is not unreasonably great. Nevertheless, not much increase is necessary to boost chemical cost appreciably, if the expensive cyclohexylamine is being used for protection of condensate return lines from corrosion. A rough idea of the significance of this statement can be obtained from the facts that approximately 2 ppm of the chemical are required to neutralize 1 ppm of carbon dioxide, and that the cost of the pure chemical is roughly 90¢ per pound.

Still another use of glassy phosphate in municipal plants, which should be discussed in connection with stabilization, is preventing the precipitation of dissolved iron or manganese (13). The procedure applies principally to well waters, to which the phosphate chemical can be added in appropriate amount before the water is contacted by oxygen or other oxidizing agent, such as chlorine. The usual feed is 2 ppm of glassy phosphate per ppm of iron or manganese. The municipal plants employing glassy phosphate for stabilization of iron or manganese will make every effort to adjust the feed properly, since it is uneconomical to feed too much and complaints are bound to follow periods of deficient chemical feed. This is fortunate from the standpoint of the boiler plants which pretreat boiler feed by base exchange, because, if the water is not completely stabilized, there is danger of fouling of the base-exchange material and consequently danger of loss of softening capacity.

Aeration

Waters high in iron and manganese frequently require aeration prior to coagulation and filtration. In other instances you aerate waters for removal of dissolved gases, such as carbon dioxide or hydrogen sulfide, or for destruction of anaerobic bacteria. Removal of all of the inorganic constituents mentioned can be helpful in the boiler plant, especially if they are present in appreciable concentrations in the natural water.

The aeration process introduces dissolved oxygen to the water. This is not of undue concern to boiler plants using the water, because it is a normal condition and the plants are usually set up to handle water containing dissolved oxygen in concentrations up to saturation (14). However, an unusual case is not only interesting but enlightening. A paper mill in California uses well water from the town mains in the low-pressure evaporators, which supply distilled makeup water for the boilers. The water, which is high in temporary hardness, is zeolite-treated, but not deaerated, before being fed to the evaporators. Because of the high sodium-bicarbonate concentration of the zeolite-treated water, evaporator-brine alkalinity has always been very high—on the order of 1,000 ppm sodium hydroxide. The plant operated for more than ten years with no trouble whatever in the evaporators, but suddenly corrosion of the arsenical-copper coils began to occur and in six months attack was severe enough to result in perforation. Thorough study of the problem led to the conclusion that oxygen, in conjunction with the large amount of carbon dioxide being driven out of solution around the coils, due to decomposition of sodium bicarbonate, was responsible for the corrosion. This mechanism was proved to be responsible by the feeding of sodium sulfite for fixation of oxygen in the evaporator water, since corrosion was arrested immediately upon application of the sodium sulfite. The question of why the plant operated so long without trouble was still not answered. The picture was completed a little later, when it was learned that the town water plant had installed an aerator to eliminate anaerobic slimes in the distribution system, and the date the new aerator was placed in operation coincided with the date corrosion of the copper coils began.

Miscellaneous

A few municipal plants are adding small amounts of sodium fluoride to the water. In the low concentrations employed this is of no significance to steam plants using the water, since effects, good or bad, should be nil.

Activated carbon, which is used for taste and odor control, is filtered out of the water and thus does not affect boiler-water conditioning one way or the other.

Ozone is rarely used but, where it is employed, the effects in the boiler plant should be similar to the effects of chlorine.

Chlorine dioxide is a newcomer in the municipal water and industrial waste treatment fields. Its primary function is taste and odor control. The use and effects of this material are not yet well understood, but it would seem that its significance in the boiler plants will not differ from the significance of chlorine.

CONCLUSION

Your first duty as municipal water-plant operating men is to produce a clear, palatable water, safe for human consumption. If, with this job done, you can economically improve the character of the water from the standpoint of using it for the generation of steam, the boiler-plant operating men will be everlastingly grateful.

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PROCEEDINGS

APRIL 1949 MEETING

AIR HOLIDAY INN, GROTON, CONN.

THURSDAY, APRIL 21, 1949

President Arthur C. King in the Chair.

The Association was welcomed by Arthur M. Card, Warden of the Borough of Groton, Conn.

President King introduced Rear Admiral James Fife, U.S.N., of the Submarine Base, New London, Conn., who spoke briefly on his experiences with water supplies throughout the world.

A paper "How Groton Meets a Growing Demand for Water" was read by Lendon F. Dutton, Superintendent, Department of Utilities, Groton, Conn.

A paper "Ten Years' Operation of the Water Filter Plant at Groton" was read by Clayton Greenleaf, Chief Operator, Filter Plant, Groton, Conn.

A paper "Revitalizing Old Water Systems" was read by Kenneth H. Holmes, City Engineer, New London, Conn.

MAY 1949 MEETING

QUABBIN RESERVOIR, WARE, MASS.

THURSDAY, MAY 19, 1949

President Arthur C. King in the Chair.

The Association was welcomed by William T. Morrissey, Chairman, Metropolitan District Commission, Boston, Mass.

A paper "Chicopee Valley Aqueduct" was read by Stanley M. Dore, Deputy Chief Engineer, Construction Division, Metropolitan District Commission, Boston, Mass.

A field inspection of the construction of the 48-inch section of the Chicopee Valley Aqueduct at Bondsville Road and of the plant manufacturing the pipe for the aqueduct on Bridge St., Palmer, Mass., followed the reading of Mr. Dore's paper.

BOOK REVIEW

Hydrology. By C. O. Wisler and E. F. Brater. xi + 419 pp. New York, N. Y.: John Wiley & Sons, Inc., 1949. $6.00

Although this book is primarily intended to fill the need for a textbook on hydrology for college and university use, it will be of value to sanitary and hydraulic engineers and others interested in hydrology, because it includes discussions of recent developments in this rapidly growing science.

The authors define hydrology as "the science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the earth." Tremendous changes have occurred in this science recently, many of the earlier concepts being replaced by sounder theories. "Two milestones mark this progress. The first, the concept of the unit hydrograph, stands as a monument to Le Roy K. Sherman. The second, the theory of infiltration capacity, is one of the many contributions of Robert E. Horton." The authors are inclined to regard "the period since 1930 as representing the dawn of the science of hydrology."

Among the concepts that have recently been outmoded is that of considering and expressing runoff as a percentage of rainfall. It is now known that "runoff is that which is left from the total rainfall after evaporation, transpiration, and various other factors have taken their toll; in other words, stream flow equals rainfall minus losses, not rainfall times a percentage factor."

The book contains the following chapters:

I. Introduction
II. The Hydrograph
III. The Drainage Basin
IV. Precipitation
V. Water Losses
VI. Infiltration
VII. Ground Water (written by John G. Ferris)
VIII. Runoff
IX. Floods
X. Stream-Flow Records

The text is interspersed with no less than 132 illustrations and there is a 9-page index. Numerous references to source material in the literature are also included.

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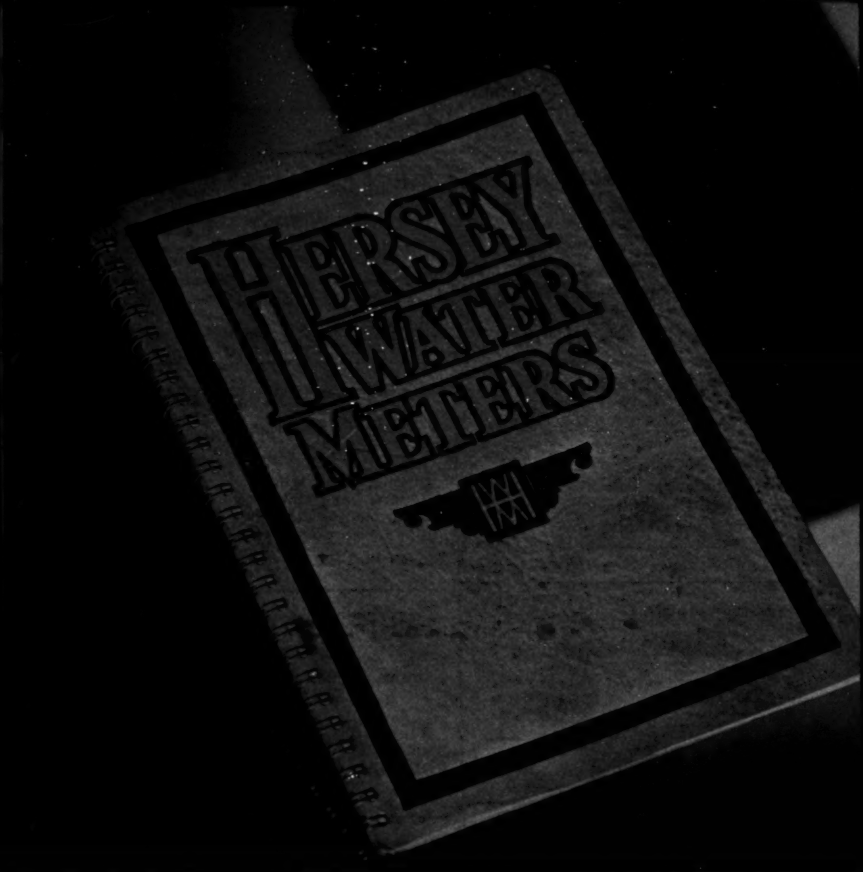

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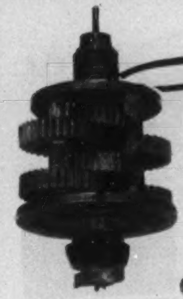
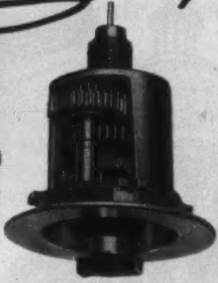
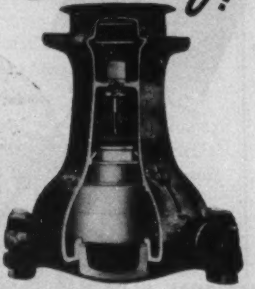


Unprotected Gear Train, removed from 1898 Trident Meter



Modern Oil-Enclosed Gear Train fits into old Trident Meter



See how easily you can modernize old Tridents

YES you can modernize old Tridents so quickly, simply, inexpensively! The shopman just picks up a modern Trident Oil-enclosed Gear Train and slips it into the old Trident meter casing. It replaces the open gear train on the old-type oil-enclosed train (5/8″, 3/4″ and 1″ meters use identical gear trains.)

And interchangeability is not limited to units. Modern parts, gears, etc. can be used to repair old units. Buy Trident Meters for TRUE standardization, which you can only get through complete interchangeability.

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Branch Offices in Chicago, San Francisco, Los Angeles, Portland, Ore., Denver, Dallas, Kansas City, Louisville, Atlanta, Boston.
NEPTUNE METERS, LTD., Long Branch, Ont., Canada

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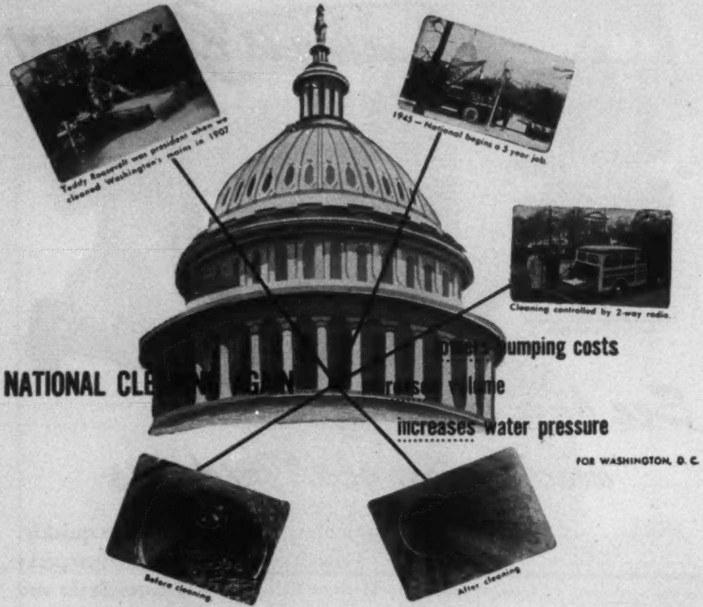
Trident Interchangeability means TRUE standardization


Teddy Roosevelt was president when we cleaned Washington's mains in 1907
1945 — National begins a 5 year job
Cleaning controlled by 2-way radio.
NATIONAL CLEANING AGAIN
lowers pumping costs
increases volume
increases water pressure
FOR WASHINGTON, D. C.
Before cleaning
After cleaning

Way back in 1907 and again in 1926 National successfully cleaned the water mains of Washington, D. C.

In 1945 a five year program to clean and recondition the entire water main system of Washington was begun and National in conjunction with the Centriline Corporation was again awarded the cleaning contract for 1945, 1946, 1947, 1948 and 1949 — *in short, the entire cleaning job!*

Tests made on those lines already cleaned and centrilined indicate a co-efficient of over 130 as against less than 90 before cleaning, resulting in lower pumping costs, increased volume and higher pressure.

Let us estimate the cost of restoring your lines to at least 95% of their original carrying capacity. Write today.

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City State

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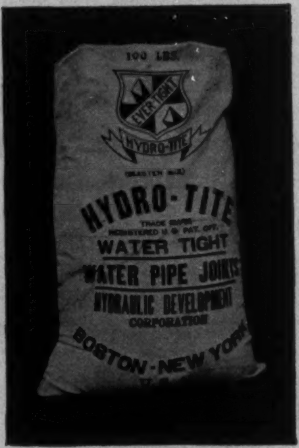
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WATER PIPE JOINTS
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CORPORATION
BOSTON-NEW YORK

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and 30 minutes

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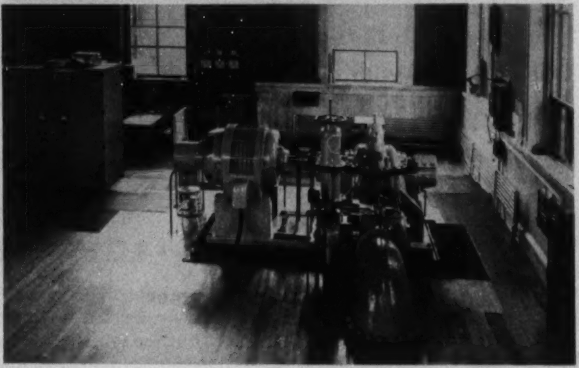
CENTRIFUGAL WATER WORKS PUMPS



City of Lynn, Mass., Walnut Street Pumping Station

The De Laval pump shown above, driven by a 500 H.P. synchronous motor, completes the modernizing of the Walnut Street Station of the Lynn Water Department. All of the other pumps in this Station are of De Laval make, and their satisfactory performance over the past years we are sure will be duplicated by the new unit.

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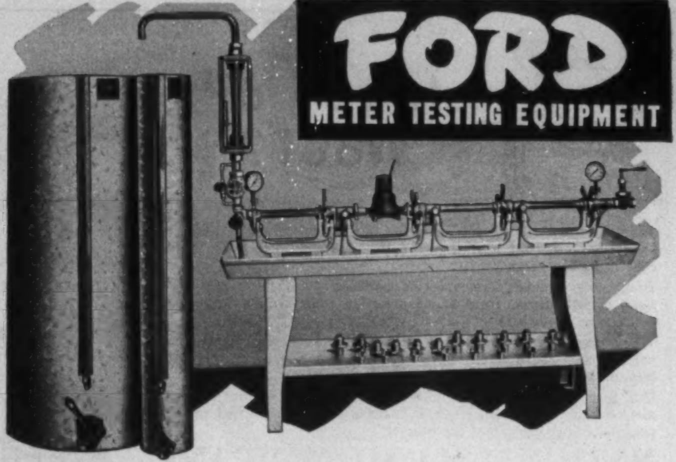

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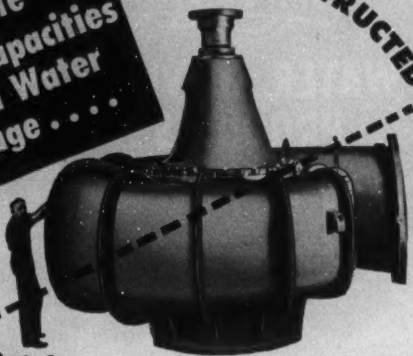
With UNOBSTRUCTED FLOW



SPECIFY *Morris* MIXED FLOW PUMPS

The most practical type of pump, in the larger sizes, for abrasion resistance and ability to handle large stringy solids without clogging.

● In the Morris Mixed Flow sewage pump there are no guide vanes in the suction, nor stationary diffusion vanes on the upstream side of the impeller, to catch longer fibrous material. High efficiencies extend over a great range of capacity. Enclosed impellers which are most generally used are better able to withstand the abrasive action of grit and dirt. Initial capacity and efficiency are maintained over a longer period of time.

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Morris Mixed Flow Pumps have no internal bearings in contact with the sewage.

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Write for your free copy of bulletin 178, describing Morris Mixed Flow Pumps

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EDDY

Valves and Hydrants

Distinctive Features of the EDDY Valves

ONLY three parts are moved by the Stem—the ball and the two gates. Each gate is hung from one of the trunnions on the ball. A convex surface at the base of each trunnion fits a concave surface on the back of the gate. This allows the gates to adjust themselves properly to their seats. . . . The gates, being free to revolve on the trunnions, do not always seat in the same position. Gates are center bearing and adjustable. They are forced to their seats with equal pressure at all points. There are two hooks on the ball on sizes 4-inch and larger, which loosely engage with the gates.

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Besides valves and hydrants to meet the most exacting demands of waterworks service, the complete EDDY Line includes: valves for sewage disposal works; valves for steam, gas and oil; check valves, foot valves, plug valves, shear gates, indicator posts, etc. EDDY valves are made in three classes: Iron Body Bronze Mounted, All Bronze, and All Iron Valves.

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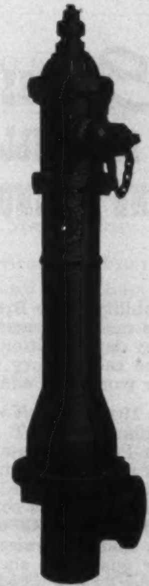
Eddy Valve Co.

WATERFORD NEW YORK



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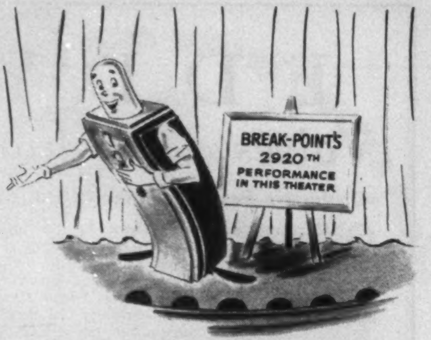

The ability of the Break-Point Process to meet the various demands of day by day operation is aptly shown by the case history of a municipal water works in Pennsylvania.

Since 1941, when it was installed at this plant by W&T Engineers, the Break-Point Process has played a major role in producing a pure, sparkling water for the system's many consumers. It has completely eliminated complaints on tastes and odors and has raised the finished water quality to such a high level that tests show *no* gas formers and *no* bacteria on the plates. In addition, a staff report continues, the Break-Point Process was of particular value in keeping the water acceptable to consumers during an emergency plant overload of 120%.

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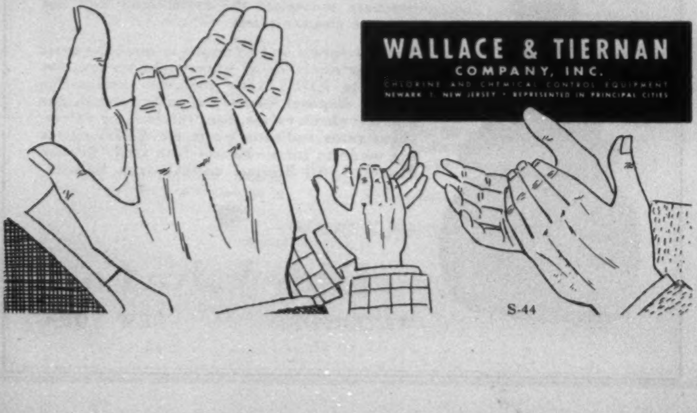
For more details write to your nearest W&T Representative — he'll be glad to help you.



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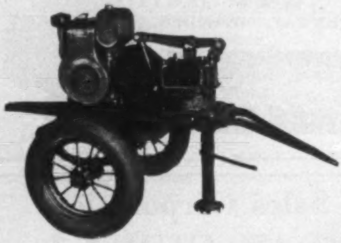

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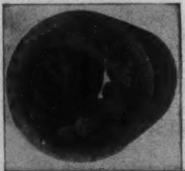

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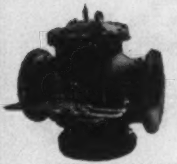

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and
reservoirs

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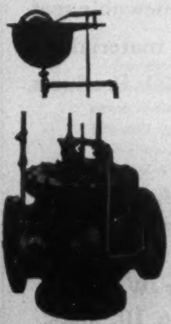

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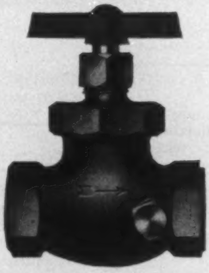

Fig. 250

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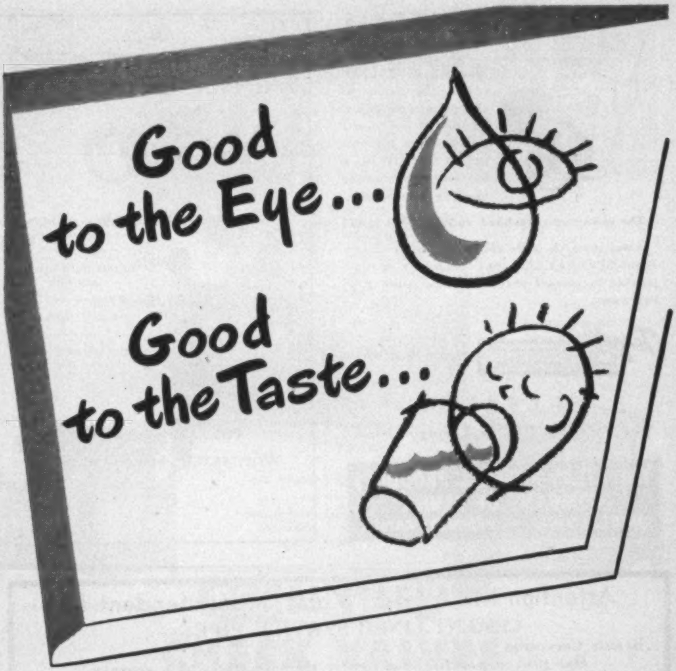
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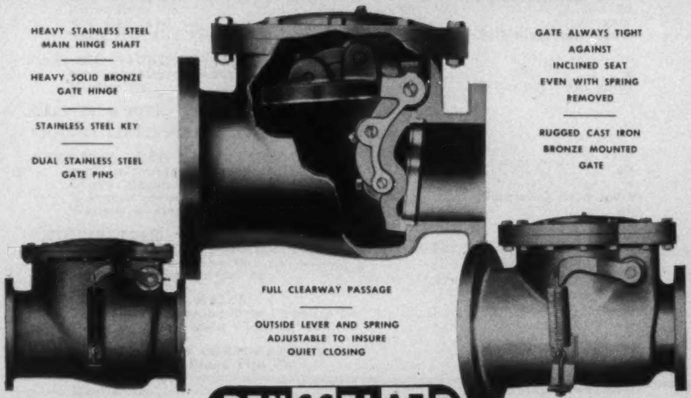

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DUAL STAINLESS STEEL GATE PINS
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STRAIGHT-THROUGH TYPE

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INCREASING TYPE

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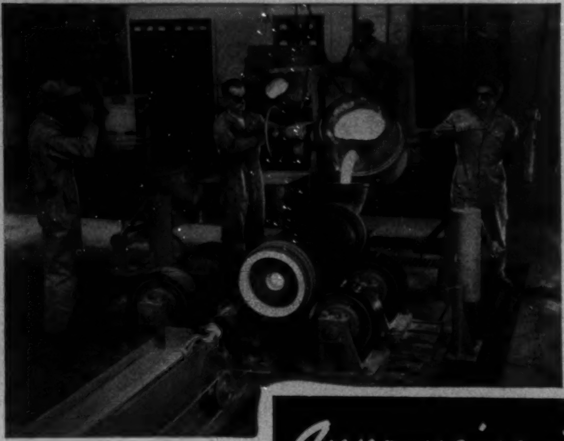

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